Development of a Prototype Micro Saint Model for Predicting Unit Performance as a Function of Unit Design

James S. Ainsworth

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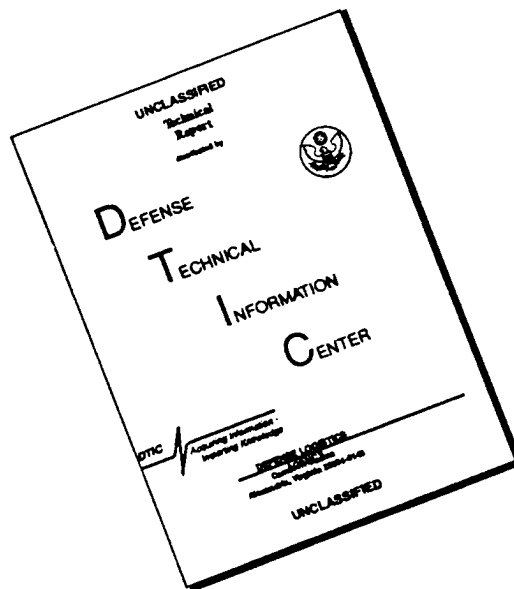# DISCLAIMER NOTICE

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1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE March 1996	3. REPORT TYPE AND DATES COVERED Final

4. TITLE AND SUBTITLE

Development of a Prototype Micro Saint Model for Predicting Unit Performance as a Function of Unit Design

5. FUNDING NUMBERS

PR: 1L162716AH70
PE: 6.27.16

6. AUTHOR(S)

Ainsworth, J. S.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARL-TN-68

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Computer simulation models that predict system and unit performance typically ignore the influence of soft factors such as personnel aptitude, training, and experience. Models being developed within the U.S. Army's MANPRINT program try to rectify this situation. The current model demonstrates the feasibility of using simulation methodology for making trade-off decisions about unit designs, such as decisions related to alternate locations, connectivities, and manning of functional communication shelters following battlefield attrition of unit assets. The model simulates performance of operations and maintenance tasks in a mobile subscriber equipment (MSE) platoon, which contains 18 communications shelters geographically dispersed to six different sites. Shelters may be linked together via cable or radio. The failure (or destruction) of a specific shelter may or may not affect the communications abilities of other shelters. In the model, the effects of shelter failures (or destructions) are represented in an effect array whose cell values are numerical codes used to simulate non-degraded, degraded, and lost communications. Shelters are represented by 18 equipment entities identified by tag values. An MSE platoon also contains 61 operators, maintainers, supporters, and supervisors. The model assigns personal identification numbers (PINs) to these personnel and uses tag values and PINs to establish shelter-personnel pairings. The pairings are set when cell values are supplied to shelter-operator and shelter-supervisor arrays. Each array contains six personnel traits: PIN of operator (or supervisor), rank, skill level, experience rating, mental category, and overall personnel quality rating. System performance and unit performance are determined by the use of hypothetical algorithms that relate personnel aptitudes and experience to model output: the number of messages relayed by specific shelter-operator-supervisor combinations.

14. SUBJECT TERMS

communications MSE
MANPRINT unit design
modeling

15. NUMBER OF PAGES
140

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

DEVELOPMENT OF A PROTOTYPE MICRO SAINT MODEL FOR PREDICTING UNIT PERFORMANCE AS A FUNCTION OF UNIT DESIGN

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March 1996

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ACKNOWLEDGMENTS

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INTRODUCTION

Design of Military Units

In considering the problem of relating unit performance to unit design, it is useful to concentrate on dynamic as well as on static determinants of optimal unit design. The blueprint of a military unit (in the U.S. Army, the Table of Organization and Equipment or Table of Distribution and Allowances) results from an analysis of the static determinants of unit design. In contrast, the real-time composition of a military unit is dynamic and may vary slowly or rapidly in response to numerous factors. These factors include planned modifications of mission requirements as well as unplanned urgencies of the battlefield.

While it is important to be able to predict unit performance as a function of a conceptualized static unit design, it would be more useful to be able to predict unit performance based on dynamic, real-world influences and to compare alternate unit designs for meeting particular mission requirements. Such designs could vary the locations, connectivities, and manning of military equipment and command posts. The factors that influence real-time unit composition are of special interest in this technical note. Among these factors are those related to the Army's system acquisition process and its MANPRINT[1] program: modifications of personnel selection procedures and personnel distributions; personnel reassignments; the results of operations and maintenance training; battlefield attrition and other changes in unit assets; anticipated and unanticipated variations in unit missions; changes in system design; and the like. The challenge is to construct analysis tools that are capable of relating such moderating variables to unit performance variables in near real time and to make the tools readily available, practical, reliable, and valid.

System Acquisition: System- Versus Unit-Level Assessment

In the past, MANPRINT efforts during the Army system acquisition process have focused on the assessment of human and system performance as a function of system design, operator aptitudes, operator training, and individual crew size. Most of these assessments

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[1] The acronym for the Army's *Manpower and Personnel Integration* program, which involves the impact of seven domains on system development, acquisition, and performance. The MANPRINT domains are manpower, personnel, training, human engineering, system safety, health hazards, and soldier survivability.

considered the static and dynamic influences on system-level performance, that is, the performance of a single system operating in isolation from other systems with which it would normally interact in the real world.

While system-level assessments are necessary parts of system development programs, MANPRINT efforts should also assess unit-level performance, in which a system is assessed within the dynamic context (either hypothetical or real) of a military unit and other systems with which it is expected to interface. The need for unit-level assessments of developing or changing systems arises from the possibility that the system-level performance of a given system may be satisfactory while its unit-level performance may prove to be unsatisfactory. In addition, performance differences among alternatively designed systems may not be evident during system-level assessments; such differences may only appear during unit-level assessments.

Unit Performance Prediction Via Computer Simulation Modeling

The ideal MANPRINT methodology for assessing the effects of system design and unit design variables on unit performance is computer simulation modeling. This relatively cost-effective methodology can be used to portray, manipulate, and analyze the main and interactive effects of a large number of independent variables on unit performance.

Prerequisites for Unit-Level Computer Simulation Modeling

Before the development of a computer simulation model is begun, the following front-end tasks must be accomplished:

- Clear unit missions and precisely quantified mission requirements must be established.

- All unit assets (such as soldiers, equipment, and supplies) must be matched to required unit functions.

- Major real-world constraints (such as availability of personnel, equipment, and supplies; existing battlefield conditions; and applicable tactics and doctrine) must be identified so that they can influence the characteristics of the model.

DEVELOPMENT OF THE MODEL

Background of Mobile Subscriber Equipment (MSE)

The U.S. Army purchased MSE because predecessor communication systems (a mixture of Army tactical communications systems [ATACSs] and integrated tactical communications systems [INTACSs]) did not support the evolving air-land battle doctrine, nor did these systems support maneuver commanders with the mobile communications necessary to accomplish assigned missions in a dynamic, rapidly changing battlefield. The current MSE network covers an area of 37,500 square kilometers (15,000 square miles) and provides area communications to a corps comprised of three to five divisions. The network covering this area consists of as many as 42 node centers (NCs) and 92 radio access units (RAUs). In total, the system provides secure, automated digitized voice, data, and facsimile communications for as many as 1,900 mobile subscribers and 8,500 wire subscribers. (See Appendix A for detailed information related to MSE background, network architecture, system features, and site configurations.)

Model Context

A prototype unit design assessment model was developed to demonstrate the feasibility of using computer simulation modeling as a methodology for making unit design trade-off decisions. The model was written in Micro Saint, a software package developed by Micro Analysis and Design, Inc. The model simulates the performance of operations and maintenance functions in an MSE platoon of an area signal company. The rationale for choosing the platoon as the unit level to be modeled was based on two factors: (a) the platoon is the lowest level unit having a variety of equipment and a variety of personnel with different military occupational specialties (MOSs), and (b) the simulation procedures encoded for a platoon model can be generalized to models simulating higher echelon units.

The MSE platoon of an area signal company is authorized 61 operators, maintainers, supporters, and supervisors who work directly with 18 communications shelters and the accompanying support equipment. The 18 MSE shelters are geographically dispersed to six different communications sites: a node center (NC), four small extension nodes (SENs), and a remote radio access unit (RAU) node. Communications among shelters at the same site are established via cable links; communications among shelters at different sites are established via radio links.

Node Center

A node center is equipped with eight shelters: a node management facility (NMF), an operations shelter (OPERATIONS), a node switch shelter (SWITCHING), four line-of-sight (LOS) radio (version 3) shelters (LOS(V3)), and a local RAU shelter. Figure 1 shows the MSE site configuration of a node center.

The Army's Field Manual 11-37 (FM 11-37), MSE Primer for Small-Unit Leaders, describes three of these shelters as follows:

The node switch (NS) consists of the switching shelter and operations shelter. The NS combines digital switching capability with flood search routing and subscriber management into one switching function. The NS provides automatic tandem switching for the MSE system. It is the hub of the MSE NC site and is the key element of area coverage [para. 2-1(a)].

The NMF provides the equipment and space required by the node platoon leader to manage the resources of the NC. The NMF interfaces with the NS operations shelter to receive operational orders and technical directives and to send network status reports [para. 2-5(e)].

The field manual also describes the importance of node centers to the overall MSE network architecture:

Node centers (NCs) are the backbone of the MSE network. These NCs are usually located on or near high points. They provide the entire corps with connectivity and switching capability. These NCs are somewhat independent of existing command structures and provide communications to the user on an area basis [paras. 1-2(a & b)].

Small Extension Nodes (SENs)

SENs 1, 3, and 4 are each equipped with two shelters: an LOS radio (version 1) shelter (LOS[V1]) and a small extension node switch (version 1) shelter (SENS[V1]). Two junction boxes (J-boxes) allow 26 wire subscribers to be connected to each SENS(V1) shelter. SEN 2 is equipped with two shelters: an LOS(V1) shelter and a small extension node switch (version 2) shelter (SENS[V2]). Four J-boxes allow 41 wire subscribers to be connected to the SENS(V2) shelter.

50 FT
CABLE
26-PAIR

OPERATIONS
SHELTER

8'
MAX

NMF

SWITCHING
SHELTER

50 FT
POWER
CABLES

TOP
VIEW
To show actual cable and shelter emplacement

(6)25 FT
INTER-
CONNECT
CABLES

PU-753
10 KW
POWER
UNIT

LOS RADIO
(V3)

15M

15M

TO
RAU

15M

5 KW
GEN

9M

TO
MSRTs

OMNI

30M
(ONE PER NODE)

POWER
CABLE

RAU(LOCAL)

LOS RADIO
(V3)

15M

SHF
OR
CABLE

5 KW
GEN

9M

CX-11230/G
COAX CABLE

COAX CABLE

5 KW
GEN

15M

COAX CABLE

1
8

NAI

SWITCHING

OPERATIONS

NODE
SWITCH

USER
CABLE

J-1077

J-1077

(2)SMD-B11236
CABLE

DNVT

10 KW
GEN

(6) INTERCONNECT
CABLES
NMF

TACSAT
AN/TSC-85A
OR
AN/TSC-93A

NODE
SUPPORT VEHICLE
3/4 TON
CARGO
TRAILER

INTERCONNECT
CABLE

NODE PLT LDR
PLT SGT

10 KW
GEN

CX-11230/G
CABLE

15M

LOS RADIO
(V3)

15M

15M

15M

5 KW
GEN

LOS RADIO
(V3)

15M

15M

5 KW
GEN

Figure 1. NC site configuration.

Parts A and B of Figure 2 show the MSE connectivities associated with a SENS(V1) node and a SENS(V2) node, respectively. FM 11-37 describes these shelters as follows:

The SENS provides for either 26 or 41 digital loops to wire subscribers. Switch version 1, that is, SENS(V1), allows 26 wire subscribers to be connected to the MSE network; switch version 2, that is, SENS(V2), allows 41 wire subscribers to be connected. The difference between the two versions is that Version 2 has additional cards in the switchboard, which give Version 2 a higher subscriber and trunk capacity [para. 2-1(c)].

The LOS radio provides point-to-point radio connection between various nodes of the MSE network. Each radio link supports a single full-duplex group level connection. In the wire subscriber segment, LOS radio links interconnect the SEN and the NS. In the area coverage segment, the LOS radio interconnects the NCs and interconnects the remote RAUs and NCs. The four LOS radio assemblages are contained in four versions: V1, V2, V3, and V4 [para. 2-2(a)]. (Note. An MSE platoon contains LOS(V1) and LOS(V3) shelters, but not LOS(V2) or LOS(V4) shelters.)

Remote RAU Node

The remote RAU node is equipped with two shelters: an LOS(V1) shelter and a remote RAU shelter. Figure 3 illustrates the connectivities associated with a remote RAU node.

FM 11-37 describes the local and remote RAU shelters as follows:

The RAU is an automatic interface between the mobile subscribers and the network. Mobile subscriber access allows mobile subscribers to place or receive calls while moving through the battle area. The mobile subscriber radiotelephone terminal (MSRT) does this by accessing the switched network via a RAU. The RAU itself does not include any switching elements, but it ensures logical control of the radio channels. Radio channel management includes managing traffic loads in the direction of "radio toward the network" and managing the necessary radio signaling protocols. The associated NS ensures management of all calls routed through a RAU. The remote RAU is collocated with an LOS(V1) for network connectivity while the local RAU is cabled directly to the NS [paras. 2-4(a & b)].

A

TO
NC
VIA
LOS(V3)

15M

LOS
RADIO
(V1)   COAX CABLE

5 KW
GEN

POWER CABLE

SMD-811235

SHF
LINK

9M

CX-11230/G
CABLE

9M

CX-4566   J-BOXES
                 J-1077

J-1077   1

13

SEN SPT VEH VRC-46   SHF
                         CABLE   SENS(V1)

USER
CABLES

OR

TACSAT
AN/TSC-85A
OR
AN/TSC-93A

J-1077   14

26

10 KW GEN

2 PAIR WF-16
COMMERCIAL
OFFICE

B

TO
NC
VIA
LOS(V3)

15M

LOS
RADIO
(V1)   COAX CABLE

SHF
CABLE

5 KW
GEN

POWER CABLE   J-BOXES
                     J-1077   1

9M

CX-11230/G
CABLE   13

OR   USER
            CABLES

4-SMD-811235

SHF
LINK

J-1077   14

CX-4566   26

SEN SPT VEH VRC-46

9M   SENS(V2)

OR   J-1077   27

TACSAT
AN/TSC-85A   SHF   34
OR   CABLE
AN/TSC-93A   USER CABLES

J-1077   35

10 KW GEN   41

WF-16
COMMERCIAL   PHONES
OFFICE

Figure 2. SENS deployment and connectivity.

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Figure 3. Remote RAU configuration.

For an MSE platoon, LOS ultra high frequency (UHF) radio links provide connectivity between an NC and a SEN, and between an NC and a remote RAU node. Figure 4 portrays the connectivities among the six communication sites of an MSE platoon. The 18 shelters assigned to a platoon are symbolized by shaded squares. The figure also illustrates the platoon's connectivities to NS shelters outside the platoon. The latter shelters are symbolized by non-shaded squares.

The 18 shelters of an MSE platoon are represented in the Micro Saint model by 18 equipment entities, with each equipment entity identified by a specific identification number or tag value between 1 and 18. Micro Saint code uses these tag values to route specific entities to specific tasks when the model is being processed. Table 1 lists the shelter, shelter location, and tag value associated with each equipment entity used in the model.
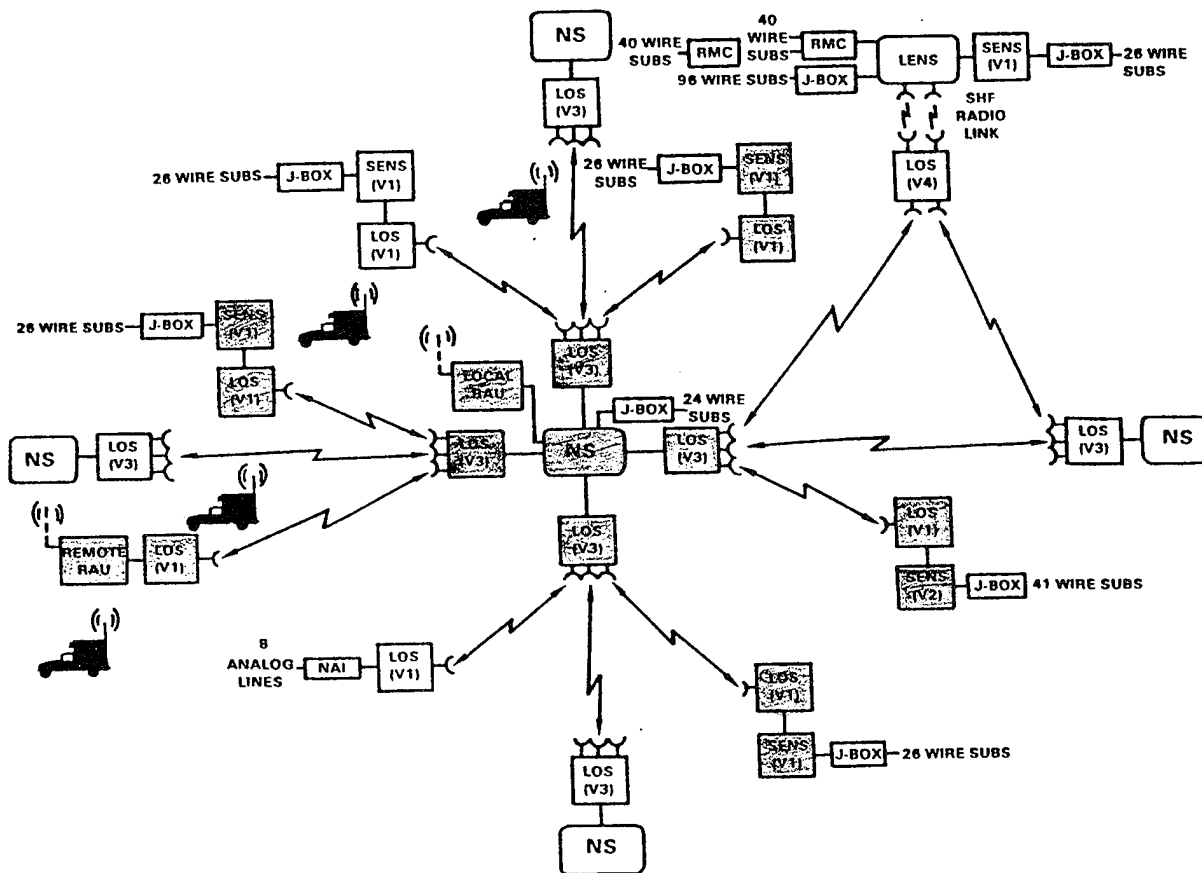
Figure 4. System connectivity.

A list of the 61 personnel assigned to an MSE platoon and the corresponding personal identification numbers (PINs) is provided in Table 2.

General Characteristics of the Model

The model uses tag values of MSE equipment (shown in Table 1) and the PINs of MSE operators and supervisors (shown in Table 2) to establish equipment-personnel pairings, that is, to establish which personnel work in which shelter. These pairings are set when initial values are supplied to two arrays: eq_p1 and eq_p2. The eq_p1 array contains equipment-operator pairings; the eq_p2 array contains equipment-supervisor pairings. Descriptions of these two arrays are provided in Appendix B (Variables 5 and 6). In the model, human performance is simulated by the use of a hypothetical algorithm that relates operational status of equipment and equipment-personnel pairings to model output. Model output is the number of messages relayed per shelter per 24-hour period.

Table 1

Shelters, Shelter Locations, and Tag Values

Shelter (equipment entity)	Location	Tag value
Node management facility	Node center	1
Operations shelter	Node center	2
Switching shelter	Node center	3
LOS(V3) Shelter 1	Node center	4
LOS(V3) Shelter 2	Node center	5
LOS(V3) Shelter 3	Node center	6
LOS(V3) Shelter 4	Node center	7
Local RAU shelter	Node center	8
LOS(V1) Shelter 1	SEN 1	9
SENS(V1) Shelter 1	SEN 1	10
LOS(V1) Shelter 2	SEN 2	11
SENS(V2) shelter[a]	SEN 2	12
LOS(V1) Shelter 3	SEN 3	13
SENS(V1) Shelter 2	SEN 3	14
LOS(V1) Shelter 4	SEN 4	15
SENS(V1) Shelter 3	SEN 4	16
LOS(V1) Shelter 5	Remote RAU node	17
Remote RAU shelter	Remote RAU node	18

[a]There is only one SENS(V2) shelter in an MSE platoon.

Table 2

Authorized MSE Platoon Personnel and Corresponding Personal Identification
Numbers (PINs) Used in the Model

Position	Grade	MOS	Number	PIN
Nodal Platoon HQ				
Platoon leader	O2	25C00	1	01
Platoon sergeant	E7	31W40	1	02
Lightweight vehicle mechanic	E4	63B10	1	03
Management shelter operator	E4	31F10	1	04
Power-generator equipment repairman	E4	52D10	1	05
Switchboard operator	E4	31U10	1	06
Node Center Section				
MSE transmission system supervisor	E7	31W40	1	07
Node center switch supervisor	E7	31W40	1	08
Node center switch operator	E6	31F30	1	09
RAU team chief	E6	31D30	1	10
MSE transmission system team chief	E6	31D30	1	11
MSE transmission system team chief	E5	31D20	3	12-14
Node center switch operator	E5	31F20	1	15
RAU operator	E5	31D20	1	16
Wire system team chief	E5	31L20	1	17
MSE transmission system operator	E4	31D10	4	18-21
Node center switch operator	E4	31F10	1	22
RAU operator	E4	31D10	1	23
Wire system installer	E4	31L10	1	24
MSE transmission system operator	E3	31D10	4	25-28
Node center switch operator	E3	31F10	1	29
Wire system installer	E3	31L10	1	30
Extension Switch Section				
Section supervisor	E7	31W40	1	31
MSE transmission system team chief	E6	31D30	2	32-33
RAU team chief	E6	31D30	1	34
Small extension switch team chief	E6	31F30	1	35
MSE transmission system team chief	E5	31D20	3	36-38
RAU operator	E5	31D20	1	39
Small extension node switch team chief	E5	31F20	3	40-42
MSE transmission system operator	E4	31D10	5	43-47
RAU operator	E4	31D10	1	48
Small extension switch operator	E4	31F10	4	49-52
MSE transmission system operator	E3	31D10	5	53-57
Small extension switch operator	E3	31F10	4	58-61

As noted, the 18 shelters are located at six different communications sites. The failure of a particular shelter may or may not affect the communications abilities of other shelters in the platoon. The types of effects that a particular shelter failure may have are depicted in the effect array. The model uses blanks and numbers (1, 2, 3, and 4) contained in this array, in conjunction with Micro Saint code, to simulate communications interdependencies among the 18 shelters. The effect array is depicted in Figure 5 and described in Appendix B (Variable 1).

As shown in the effect array, some shelter failures have more debilitating effects on an MSE platoon than do other shelter failures. For instance, the failure of Shelter 2 (operations shelter) or Shelter 3 (switching shelter) has a maximum debilitating effect on the MSE platoon's ability to communicate. In both cases, the output of the model (the number of messages relayed per shelter per 24-hour period) would be maximally affected. Other output variables, such as call completion rate, message completion rate, speed of service, grade of service, average subscriber usage factor, off-hook factor, and average call-holding time, could be added to the current model to enhance its utility. Additional Micro Saint code would have to be written to accommodate these variables. This code could be written by any analyst familiar with Micro Saint software and familiar with the operational definitions of communications-related terms such as "call completion rate" and "off-hook factor." The ability to analyze a variety of output variables would improve the model's utility for

- assessing alternate unit designs with various levels of the following four factors:

    –personnel quantity
    –personnel quality
    –equipment quantity
    –equipment quality

- providing unit designers with information pertaining to trade-offs among these four factors.

Affected Shelter

Failed Shelter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	4																	
2	3	4	3	3	3	3	3	3	2	1	2	1	2	1	2	1		
3	3	3	4	3	3	3	3	3	2	1	2	1	2	1	2	1		
4				4					2	1								
5					4						2	1						
6						4							2	1				
7							4								2	1		
8								4										
9									4	1								
10									3	4								
11											4	1						
12											3	4						
13													4	1				
14													3	4				
15															4	1		
16															3	4		
17																	4	3
18																	3	4

Legend: The blank or number in each cell represents the effect that a failure of shelter in row has on the communications ability of shelter in column:

Blank — No effect
1 — Degrades (affected shelter retains ability to relay local traffic only)
2 — Eliminates (affected shelter attempts to establish radio link to an alternate, operational shelter)
3 — Eliminates (affected shelter remains idle until failed shelter is repaired)
4 — Eliminates (failed shelter remains idle until it is repaired)

Figure 5. Effect array showing interdependencies among 18 shelters in an MSE platoon.

Mechanics of the Computerized Model

A diagram of the networks and tasks (numbered 1 through 26) and the associated decision nodes, queues, and paths traversed by the entities in the Micro Saint model[2] is presented in Figure 6. Networks, which are symbolized by rectangular boxes, are underlain with other networks or tasks. Tasks, which are symbolized by oval boxes, are not underlain with other tasks or networks.

In the model, node center operations are represented by Network 6. Single clicking on the network symbol,

6
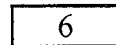
and then single clicking on the down button will show the following tasks underlying Network 6:

Task number	Task name
97	dummy
90	operate NMF
91	operate OPS
210	operate NS
92	operate LOS(v3) 1
93	operate LOS(v3) 2
94	operate LOS(v3) 3
95	operate LOS(v3) 4
96	operate local RAU
98	dummy

Double clicking on any task symbol in the list will display the Task Description window, which provides the task number, name, timing information, release condition, and execution effects for the task. For example, Task 90 is named "operate nmf." An equipment entity starting this task stays there for 10 minutes (simulation time), then triggers the Micro Saint code placed in the ending effect block. (Appendix B defines the variables used in the ending effect block.)

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
[2]To best understand how Micro Saint code is used to simulate the communications functions of an MSE platoon, some reader familiarity with Micro Saint software would be helpful. (Note. The Micro Saint file unit_6.mod, provided with Micro Saint release 1.1a with ActionView [1992] for Microsoft Windows 3.1, presents a diagram identical to the one shown in Figure 6.)
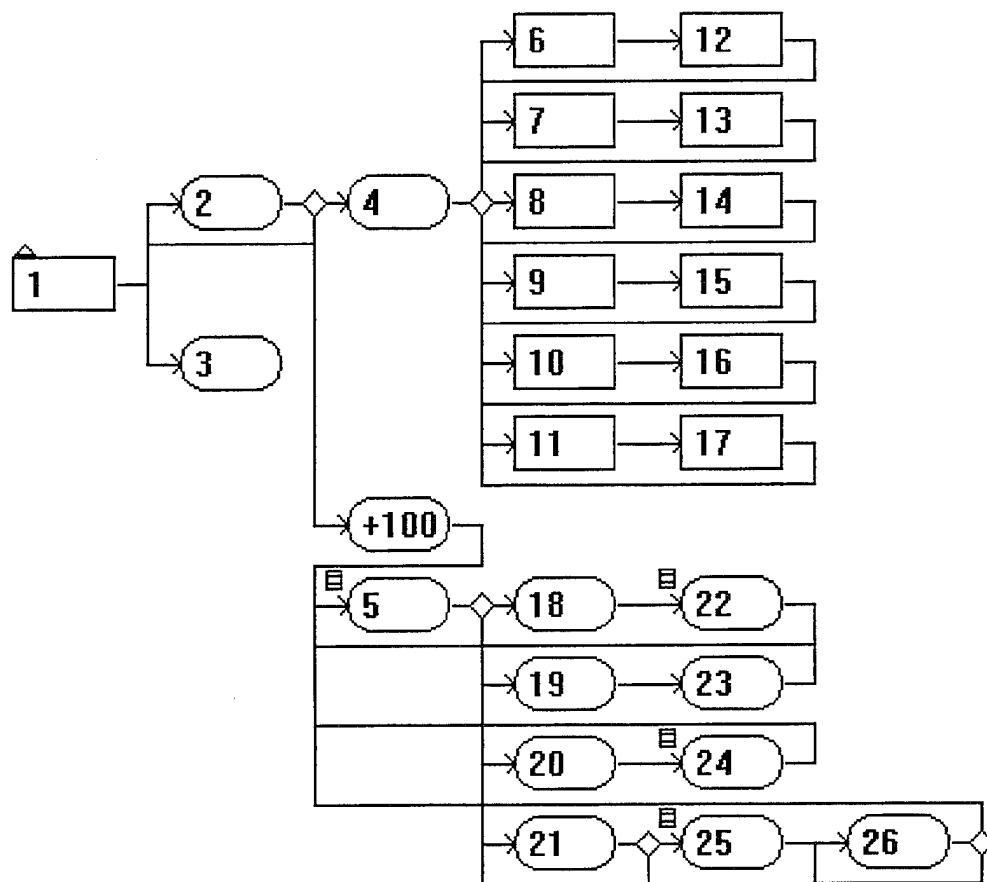
Legend:

Network 1	--	Installation
Task 2	--	Spinner task
Task 3	--	END OF RUN
Task 4	--	Equipment entity processor
Task +100	--	Control entity processor
Task 5	--	Fully operational
Network 6	--	Node center operations
Network 7	--	Small extension node #1 operations
Network 8	--	Small extension node #2 operations
Network 9	--	Small extension node #3 operations
Network 10	--	Small extension node #4 operations
Network 11	--	Remote RAU operations
Network 12	--	Node center non-operations
Network 13	--	Small extension node #1 non-operations
Network 14	--	Small extension node #2 non-operations
Network 15	--	Small extension node #3 non-operations
Network 16	--	Small extension node #4 non-operations
Network 17	--	Remote RAU non-operations
Task 18	--	Operational (local only)
Task 19	--	Non-operational (restore)
Task 20	--	Non-operational (up but idle)
Task 21	--	Non-operational (down)
Task 22	--	Op (local only)
Task 23	--	Non-op (restore)
Task 24	--	Non-op (up but idle)
Task 25	--	Non-op (down)
Task 26	--	Op (repaired)

Figure 6. Networks and tasks associated with the prototype unit design assessment model.

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Double clicking on the decision node symbol, ◊ , displays a Description of Decision window, which presents the logic used to route entities to Tasks 90, 91, 210, 92, 93, 94, 95, and 96. In this model, an equipment entity is routed to a particular task based on the tag value given to the entity.

Double clicking on a queue symbol, ▤ , in the lower portion of the model, brings forward a Job Queue Description window, which gives six types of information related to a queue: queue number, name, sorting order, entering effect, priority, and departing effect. The model uses this information when entities are entered into, stored within, or released from queues.

Equipment Entities (Operations Module)

The 18 equipment entities (with tag values 1 through 18) are used in the upper, or operations, portion of the model to represent the 18 shelters.[3] The operational state of a shelter (i.e., continuous operations versus shelter failure) is simulated as follows:

Each equipment entity flips back and forth between an operations network and a non-operations network. (In Figure 6, Networks 6 and 12 correspond to operations and non-operations networks for the node center site; Networks 7 and 13 correspond to operations and non-operations networks for SEN 1; Networks 8 and 14 correspond to operations and non-operations networks for SEN 2; Networks 9 and 15 correspond to operations and non-operations networks for SEN 3; Networks 10 and 16 correspond to operations and non-operations networks for SEN 4; and Networks 11 and 17 correspond to operations and non-operations networks for the remote RAU node.) To simulate continuous operations, an equipment entity is held in the operations network for 10 minutes before being flipped to the non-operations network. For example, equipment entity (tag value 1) stays in Task 90 under Network 6 for 10 minutes. The entity is then transferred to Network 12 where it is instantaneously passed on, via a probabilistic decision node. If passed to Network 45 (continued operations), Task 48 (the sole task under Network 45, with no simulation time associated with it) instantaneously flips the entity back to Network 6, with no simulation time spent in a non-operations mode.

In contrast, to simulate a shelter failure, the model probabilistically sends an equipment entity in a non-operations network to an unscheduled mx (maintenance) network, where it is

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[3]Note. The upper portion of the model refers to Task 4 and Networks 6 through 17 (see Figure 6).

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routed to a troubleshoot task, and eventually to a perform unit level mx task. The beginning effect of the troubleshoot task sets three variables (dest[tag], select1[tag], and failed[tag]) to values used to process entities in a manner that simulates the interdependencies among the shelters of an MSE platoon. To simulate a shelter repair, the model releases an equipment entity from a perform unit level mx task. When the entity is released, the ending effect of the perform unit level mx task sets two variables (select2[tag] and failed[tag]) to values used to process interdependent entities in the model. (See Appendix B for definitions of these variables.)

Control Entities (Control Module)

The lower portion of Figure 6 represents the model's control schema for simulating the interdependencies and their effects among the 18 shelters represented in the upper portion of the figure. An interdependency would be exhibited, for example, between Shelters 9 and 10 if Shelter 9 failed. In this case, communications in Shelter 9 would terminate and communications in Shelter 10 would be degraded until Shelter 9 is repaired. The behavior of equipment entities simulates the real-world effects of changing operational circumstances (i.e., failures or destruction of MSE shelters). In the model, the behavior of equipment entities is regulated via control entities.

The 18 control entities, with assigned tag values 101 through 118, operate in the lower portion of the model and interact with the 18 equipment entities in the upper portion of the model. The control entity with tag value 101 is paired with the equipment entity with tag value 1; the control entity with tag value 102 is paired with the equipment entity with tag value 2, and so on. The control entities are used in combination with the effect values from the effect array (see Figure 5) to implement the performance consequences of shelter failures and shelter repairs. The control entities function in Task 5 and Tasks 18 through 26 (see Figure 6).

The interplay between the model's operations module and control module is made possible by the numbering scheme for the equipment and control entities, and by the Micro Saint code, which uses the moment-to-moment values of Micro Saint variables and constants in its decision logic. (See Appendix B for a list and description of these variables and constants.)

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OPERATION OF THE MODEL

The model is processed in minutes and a model run consists of two 720-minute segments. These two segments represent two 12-hour work shifts for shelter operators. Each shift is divided into two 360-minute periods, simulating two 6-hour supervisory work periods for shelter supervisors. MSE manning is such that operators do not work consecutive shifts and supervisors do not work consecutive periods. Thus, the model has a different mix of operators and supervisors for each of four 6-hour segments: shift 1/period 1, shift 1/period 2, shift 2/period 3, and shift 2/period 4.

Starting

The model begins with Network 1 (installation) where Task 1a (install wire links) and Task 1b (set radio links) are performed sequentially by the wire system installers and the MSE shelter operators, respectively. A multiple decision node follows Task 1b. At this point, the generic entity that starts the model is transformed into two generic entities. One is sent to Task 2 (spinner); the other is sent to Task 3 (END OF RUN). The entity sent to Task 3 (END OF RUN) stays there until the clock variable equals 1440; at this time, the entity halts the model run.

The entity sent to the spinner task (Task 2) is assigned a tag value of 1 at the ending effect of Task 2. This entity then goes to a multiple decision node that transforms it into three entities (all with tag values equal to 1). One of the three entities is sent to Task 4 (which processes equipment entities); one is sent to Task +100 (which processes control entities); and one is returned to Task 2 (the spinner task).

The entity that is returned to Task 2 has its tag value changed from 1 to 2 at the ending effect of Task 2. Like its predecessor, this entity goes to the multiple decision node, which transforms the entity into three entities (all with tag values equal to 2). As before, one entity is sent to Task 4, one is sent to Task +100, and one is sent back to Task 2. This spinner and multiple-decision-node process continues until 18 equipment entities (with tag values 1 through 18) and 18 control entities (with tag values 101 through 118) have been created.

Each equipment entity in the operations module (upper portion of the model) is paired with a control entity in the control module (lower portion of the model). That is, the equipment entity with tag value 1 is paired with the control entity with tag value 101; equipment entity with tag value 2 is paired with the control entity with tag value 102, and so on. A degree of

operational realism for the MSE platoon is achieved in the model via Micro Saint interplay between these pairs, and via interplay among equipment entities representing failed shelters and equipment entities representing shelters linked to failed shelters (see effect array in Figure 5).

Distribution of Equipment Entities to Operations Networks

Each equipment entity is sent to Task 4 (the equipment entity processor). When the entity leaves Task 4, it is sent to a tactical decision node that routes it to one of the six operations networks representing the six geographically dispersed communications sites in a platoon. The routing of a particular equipment entity to its proper network in the model is accomplished via Micro Saint code using the tag value assigned to the entity. (See Figures 1, 2, 3, and 4 for diagrams of the interconnections among communications sites and Figure 6 for a graphic representation of the model.) The 18 equipment entities are distributed as follow:

- Eight equipment entities (with tag values 1 through 8) are routed to Network 6, which represents the operations of the node center. These eight entities correspond to the node management facility, the operations shelter, the switching shelter, the LOS(V3) Shelter 1, the LOS(V3) Shelter 2, the LOS(V3) Shelter 3, the LOS(V3) Shelter 4, and the local RAU shelter.

- Two equipment entities (with tag values 9 and 10) are routed to Network 7, which represents the operations of the small extension node 1. The two entities correspond to the LOS(V1) Shelter 1 and the SENS(V1) Shelter 1.

- Two equipment entities (with tag values 11 and 12) are routed to Network 8, which represents the operations of the small extension node 2. The two entities correspond to the LOS(V1) Shelter 2 and the SENS(V2) shelter.

- Two equipment entities (with tag values 13 and 14) are routed to Network 9, which represents the operations of the small extension node 3. The two entities correspond to the LOS(V1) Shelter 3 and the SENS(V1) Shelter 2.

- Two equipment entities (with tag values 15 and 16) are routed to Network 10, which represents the operations of the small extension node 4. The two entities correspond to the LOS(V1) Shelter 4 and the SENS(V1) Shelter 3.

• Two equipment entities (with tag values 17 and 18) are routed to Network 11, which represents the operations of the remote RAU node. The two entities correspond to the LOS(V1) Shelter 5 and the remote RAU shelter.

Functioning of the Operations Module

The overall structure of the upper portion of the model (operations Networks 6 through 11 and non-operations Networks 12 through 17) simulates the 18 MSE shelters operating at six different sites, and the effects that shelter failures have on unit performance, that is, number of messages relayed per time interval. Micro Saint code causes each simulated shelter to operate for 10 minutes. Each shelter relays a varying number of messages during that time. The number of messages relayed depends upon a non-research-based algorithm developed by the researcher. The algorithm is based on a quantitative relationship between overall quality of operator-supervisor combinations and the number of messages relayed by particular operator-supervisor-equipment combinations. Aptitude and experience data for operators (contained in the eq_p1 array) and for supervisors (contained in the eq_p2 array) are used to determine overall quality of operator-supervisor combinations (contained in the eq_p1_p2 and crew arrays). (See Appendix B for descriptions of these arrays.)

For an example of the coded algorithm, see the Micro Saint code for the ending effect of Task 89 under Network 7. In the example, the overall quality rating of a Shelter 9 crew is represented by the sum of the overall quality rating of a Shelter 9 operator and the overall quality rating of a Shelter 9 supervisor (with lower ratings being better than higher ratings). If the overall quality rating of a Shelter 9 crew is < 10, then 40 messages will be relayed during a 10-minute operating period. If the rating is > 10 but ≤ 15, 30 messages will be relayed. If it is > 15 but ≤ 20, 20 messages will be relayed, and if it is > 20, 10 messages will be relayed.

After a particular equipment entity has operated for 10 minutes (and has relayed a certain number of messages), it is transferred to a specific non-operations network where it flows probabilistically to one of three underlying networks:

• Continued operations--which basically does nothing but route the entity back to the proper operations network. This simulates continuous operations with no downtime for equipment adjustment or unscheduled maintenance.

• Equipment adjustment--which simulates the adjustment of communications equipment to improve wire and radio links. When equipment adjustment is completed, the shelter is considered to be operational; therefore, equipment entities are routed back to appropriate operations networks.

• Unscheduled maintenance--which simulates the troubleshooting of a shelter failure, the decision concerning whether unit-level maintenance can correct the problem, the decision whether repair parts are readily available at unit level, and the actual performance of unit-level maintenance. When unscheduled maintenance is completed, the shelter is considered to be operational; therefore, equipment entities are routed back to the appropriate operations networks.

In general, equipment entities flip-flop between operations and non-operations networks for the entire 1,440 minutes of a computer simulation run. Model variables (msg1 for entity 1, msg2 for entity 2, etc.) are used to store the most recent number of messages relayed per shelter during a 10-minute operational period and to store the cumulative number of messages (msg1cum, msg2cum, etc.) relayed per shelter since the beginning of the model run.

Functioning of the Control Module

The overall structure of the lower portion of the model (Task +100, Task 5, and Tasks 18 through 26, as shown in Figure 6) simulates the effects of a shelter failure on the failed shelter and on all shelters linked to the failed shelter. The lower portion also simulates the effects of a shelter repair on the repaired shelter and on all other shelters linked to the repaired shelter. The flip-flopping of the equipment entities in the upper portion of the network affects the movement of the control entities in the lower portion, and vice versa.

Example Simulation

The interplay between equipment entities and their associated control entities is illustrated in the example box. The interplay, as a whole, simulates real-world operations in an MSE platoon. In the example, a failure of Shelter 9, the LOS(V1) shelter located at small extension node 1, is simulated.[4]

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[4] The reader may find the example more helpful by referring to the computerized version of the model.

EXAMPLE SIMULATION

(interplay between equipment and control entities)

After operating for 10 minutes in Network 7 in the upper portion of the model, equipment entity (tag value 9) is transferred to Network 13. Within this network, the entity is probabilistically routed to Network 60 (unscheduled maintenance). The beginning effect for Task 61, the first task in Network 60, changes the values in three arrays: It changes select1[9] from 0 to 1; it changes failed[9] from 0 to 1; and it changes dest[9] from 0 to 4. These three variables with their new values are used to alter the location of control entity (tag value 109) in the lower portion of the model: The control entity is removed from q5 when select1[9] is set to 1, and is sent to Task 21 because dest[9] was set to 4.

The beginning effect for spinner Task 21 in the lower portion of the model determines which equipment entities in the upper portion and which control entities in the lower portion are affected by the failure of Shelter 9, and the subsequent release of control entity (tag value 109) from q5. This determination is made when the computer software iterates through Row 9 of the effect array, i.e., when the software discovers that effect[9,9] = 4, that effect[9,10] = 1, and that all other cells in the row = 0.

When the iteration process determines that effect[9,10] = 1 and dest[10] = 1, two things happen: Control entity (tag value 110) is withdrawn from q5 and routed to Task 18 and then to q22, and the task being performed in the upper portion of the model by equipment entity (tag value 10) is suspended in place-- wherever it is in the operations network. (The latter is implemented by the use of the suspendTasks function in Micro Saint.)

When control entity (tag value 109) has completed its spinning through Task 21 (i.e., completed its iterating through Row 9 of the effect array), it is routed to q25, where it remains until equipment entity (tag value 9) is repaired in the upper portion of the model. The elapsed time that equipment entity (tag value 9) stays in Network 60 (unscheduled maintenance) is equal to the elapsed time that control entity (tag value 109) stays in q25; the elapsed time that equipment entity (tag value 10) remains in a task-suspended status is equal to the elapsed time that control entity (tag value 110) stays in q22; and all four of these elapsed times are identical.

A similar chain of events occurs when equipment entity (tag value 9) is repaired in the upper portion of the model--that is, in Network 13 at Task 64 (perform unit- level maintenance). The ending effect for Task 64, the last task in this network, changes the values in two arrays: It changes select2[9] from 0 to 1, and it changes failed[9] from 1 to 0. The current values of these two variables are used in Micro Saint code to alter the location of control entity (tag value 109) in the lower portion of the model. The control entity is removed from q25 when select2[9] is set to 1.

The beginning effect for spinner Task 26 in the lower portion of the model determines which equipment entities in the upper portion and which control entities in the lower portion are affected by the repair of Shelter 9, and the subsequent release of control entity (tag value 109) from q25. This determination is made by iterating (as before) through Row 9 of the effect array. When the iteration process determines that effect[9,10] > 0, two things happen: Control entity (tag value 110) is withdrawn from q22 and sent back to q5, and the task being performed by equipment entity (tag value 10) when it was suspended is resumed in place--wherever it is in the operations network. (The latter is implemented by use of the resumeTasks function in Micro Saint.)

When control entity (tag value 109) has completed its spinning through Task 26 in the lower portion of the model (i.e., has finished iterating through Row 9 in the effect array), it is routed back to q5, where it remains until equipment entity (tag value 9) fails again or another shelter fails that affects the operation of Shelter 9. For example, if Shelter 10 fails, Shelter 9 goes into a not-operating [idle] mode, which is simulated by moving control entity (tag value 110) from q5 to q25 and moving control entity (tag value 109) from q5 to q24.

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MODEL RESULTS

A verification process for the unit design assessment model was conducted in two phases. Phase 1 ensured that the Micro Saint software and user-written code processed the equipment and control entities as expected, that output files accurately recorded individual transactions (such as entries and exits from q25, the "failed shelter" queue), and that output files accurately recorded cumulative statistics (such as total number of messages relayed by a particular shelter during 24 hours of operations). For Phase 1, the unit_6.mod file was run for three iterations. The overall quality ratings for operators and supervisors (contained in two input arrays: eq_p1 and eq_p2) were based on logical assignments of personnel to crews, that is, low, medium, and high aptitude crew members were dispersed equitably throughout the platoon. Data from the three runs for Phase 1 analyses were stored in four Micro Saint output files: data1.res, data2.res, data3.res, and data4.res. The contents of these files are presented in Appendix C.

The data1.res output file contains the current values of 20 variables (run, clock, msg1cum, ... msg18cum) when each of three snapshots was taken. In each of these runs, the trigger for each snapshot was the occurrence of clock = 1440. The data represent the total number of messages relayed by each shelter during a 24-hour operational period (1,440 minutes). Each run of the model represented one 24-hour operational period.

The data2.res output file contains the current values of 38 variables (run, clock, crew[1], msg1cum, ... crew[18], msg18cum) when each of 15 snapshots was taken. In each of the three runs, the trigger for each snapshot was the occurrence of clock = 0, 360, 720, 1080, or 1440. The data represent the overall quality rating for the crew assigned to each shelter and the total number of messages relayed by each shelter during a 6-hour operational period (360 minutes). Each run of the model represents four 6-hour operational periods.

The data3.res output file contains the current values of three variables (run, clock, and tag) when each of 501 snapshots was taken. In each of the three runs, the trigger for each snapshot was the entry of a control entity into q25. The data represent the clock time when a particular shelter failed.

The data4.res output file contains the current values of six variables (run, clock, tag, in_q25, out_q25, and downtime) when each of 474 snapshots was taken. In each of three runs, the trigger for each snapshot was the departure of a control entity from q25. The data represent

the clock times necessary to compute how long a particular shelter was in a failure mode (i.e., the downtime for that shelter).

Phase 2 of the verification process ensured that the hypothetical algorithm that relates crew aptitude to crew performance accurately influences the outcomes of the model. For this sensitivity analysis, the overall quality ratings for the crews assigned to Shelters 3, 9, 10, 17, and 18 were set as small numbers for three runs of the model; were set as medium numbers for three runs of the model; and were set as large numbers for three runs of the model. (Small numbers in the eq_p1_p2 and crew arrays are associated with crews with high aptitudes; medium numbers are associated with crews with medium aptitudes; and large numbers are associated with crews with low aptitudes.) The hypothetical algorithm encoded the notion that shelters manned with high aptitude crews transfer large numbers of messages per 24-hour mission, shelters manned with medium aptitude crews transfer medium numbers of messages per 24-hour mission, and shelters manned with low aptitude crews transfer small numbers of messages per 24-hour mission. The data1.res and data2.res output files associated with these nine runs of the model are presented in Appendix D. The data associated with Shelters 3, 9, 10, 17, and 18 for these nine runs are presented graphically in Figure 7. As expected, the data illustrate that high aptitude crews transfer more messages per unit time than do medium aptitude crews; and medium aptitude crews transfer more messages per unit time than do low aptitude crews.

CONCLUSIONS

Many of the modeling concepts and techniques used in this Micro Saint model of an MSE platoon's operations and maintenance functions are equally applicable to future models that strive to assess the utility of alternate unit designs. For example, the use of matrices (or arrays) containing multiple effect codes is an efficient technique for simulating the multiple effects of a single action on the performance of an interdependent network of connected entities (such as pieces of military equipment, computer systems, or military organizations participating in joint operations). The use of matrices (or arrays) containing work unit-personnel assignments, as well as "soft" information about the personnel assigned to particular pieces of equipment, work units, or organizations, is an efficient technique for inputting "soft" factors such as personnel aptitude, achievements during training, and experience. Having access to these variables, a modeler can readily implement human aptitude-human performance algorithms. The algorithm used in this model was a hypothetical one; algorithms used in future models should be research-based regression equations that use "soft" factors as human performance predictor variables. Alternate

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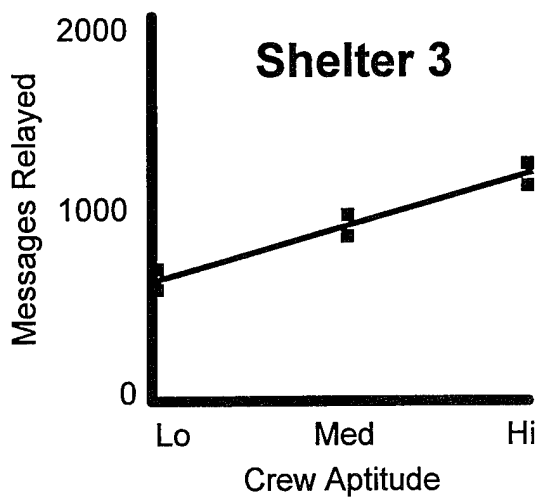
Note:
Angled lines in graphs connect average messages relayed by shelters manned with low-, medium-, and high-aptitude crews (3 model runs for each type crew).
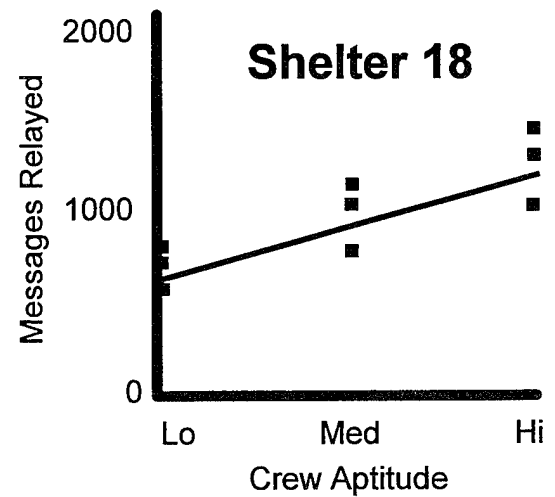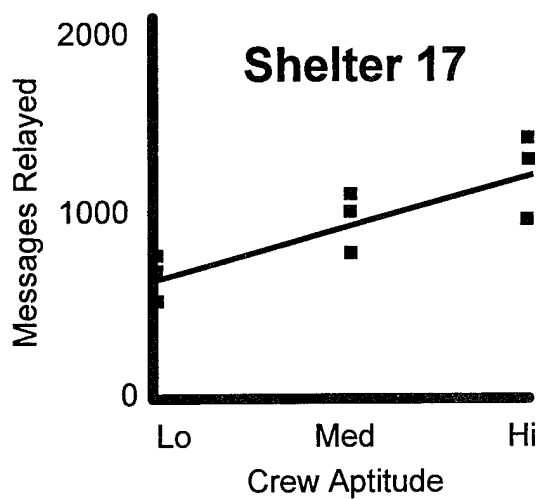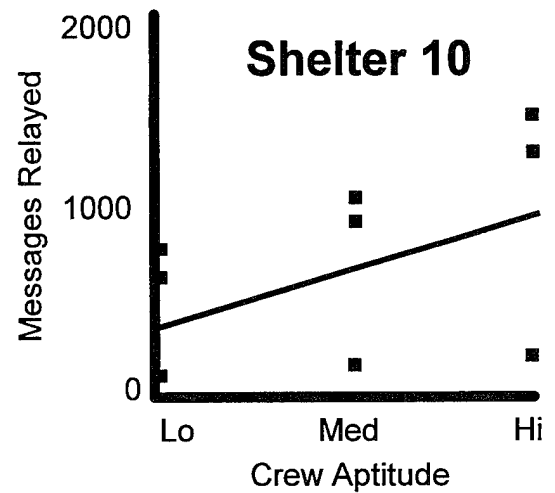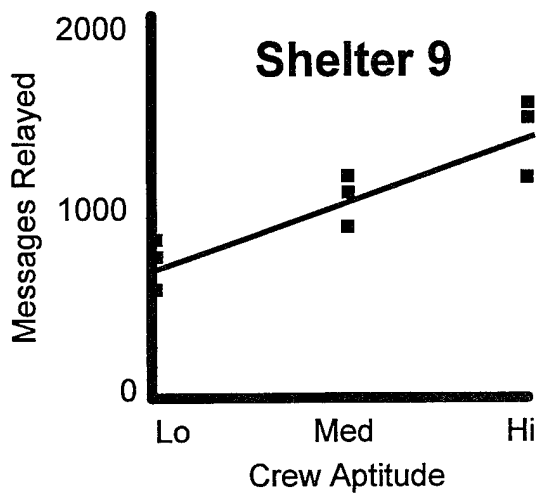
Figure 7. Model messages that show the effects of crew aptitudes on cumulative messages relayed by five MSE shelters.

unit designs could then be validly assessed by varying the quality and quantity of available equipment, as well as the quality and quantity of available personnel.

The current prototype model is far from being sufficiently realistic to warrant its use by combat developers or unit designers. To date, its development has reached only the end of a verification-of-prototype stage. Future research with this and other MANPRINT models should place great emphasis on the validation process, that is, on ensuring that the models accurately reflect the effects of dynamic, real-world environments and mission requirements. The validation process will depend heavily on the contributions of numerous subject matter experts.

APPENDIX A

CHAPTER 1 OF FIELD MANUAL 11-37,
MSE PRIMER FOR SMALL-UNIT LEADERS

CHAPTER 1

Doctrinal Concepts

1-1.   Background

a.   The Army purchased Mobile Subscriber Equipment (MSE) because of evolving doctrine and the need to modernize tactical communications. To keep up with AirLand Battle doctrine, the Signal Corps had to reconsider the means used to provide command and control (C^2) to corps and division commanders.

b.   The equipment that MSE replaces, a mixture of Army Tactical Communications Systems (ATACSs) and Integrated Tactical Communications Systems (INTACSs), did not support AirLand Battle doctrine. Nor did it provide the maneuver commander with the mobile communications needed to accomplish the mission in a dynamic, rapidly changing battlefield.

c.   The corps signal brigade becomes the focal point for signal C^2. In coordination with the divisions, the corps controls the maneuver of signal elements over the battlefield. MSE provides the commander with communications support throughout the corps area and extends his voice over the battlefield even when he is mobile. MSE--

*   Supports AirLand Battle doctrine.

*   Is highly mobile.

*   Allows no single node to be critical to the network's survival.

*   Uses the same equipment and organizational baseline at corps and division.

*   Uses less cable and wire.

*   Is rapidly set up and torn down.

*   Is common-user oriented.

*   Is less vulnerable to enemy targeting.

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● Requires fewer signal soldiers to install, operate, and maintain communications.

● Provides subscribers with continuous communications even during movement.

● Automates network management.

● Uses a fixed directory numbering plan.

● Provides universal access to other networks.

● Uses flood search to automatically route calls over the best available path.

● Uses flood search to eliminate the need for circuit routing tables.

● Meets the Air Force standards for air transportability.

1-2. MSE Network Architecture

a. Node centers (NCs) are the backbone of the MSE network. These NCs are usually located on or near high points. They provide the entire corps with connectivity and switching capability. These NCs are somewhat independent of existing command structures and provide communications to the user on an area basis.

(1) As the corps commander maneuvers the combat units, the MSE network deploys to support these elements. The direction of maneuver and the location of combat, combat support, and combat service support units dictate the placement of communications units. MSE supports subscribers at echelons from corps through battalion level command posts (CPs). It does not replace the data distribution or combat net radio (CNR) architectures.

(2) As the corps commander's concept of maneuver evolves, NCs and extension nodes are deployed to support this concept. As the corps battlefield requires less communications support, the NCs and extension nodes are redeployed to an area requiring more support or maintained in reserve to meet future requirements. (See Figure 1-1.)

b. The MSE network provides area communications to a corps made up of three to five divisions and covering an area of 37,500 square kilometers (15,000 square miles). (See Figure 1-2.) The network covering this area consists of up to 42 NCs and 92 radio access units (RAUs). In total, the system provides service for up to 1,900 mobile subscribers and 8,500 wire subscribers. Appendix A covers MSE interoperability with echelons above corps (EAC).

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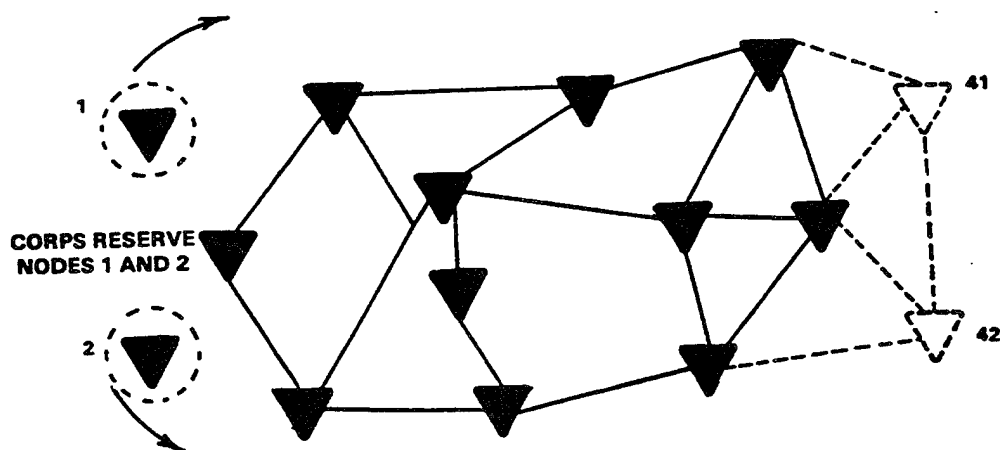
NOTE: Nodes 41 and 42 are deployed to support the increasing need for communications. Reserved nodes 1 and 2 will be redeployed forward because they are no longer required in their present location or maintained in reserve to meet future requirements.

Figure 1-1. Node deployment.
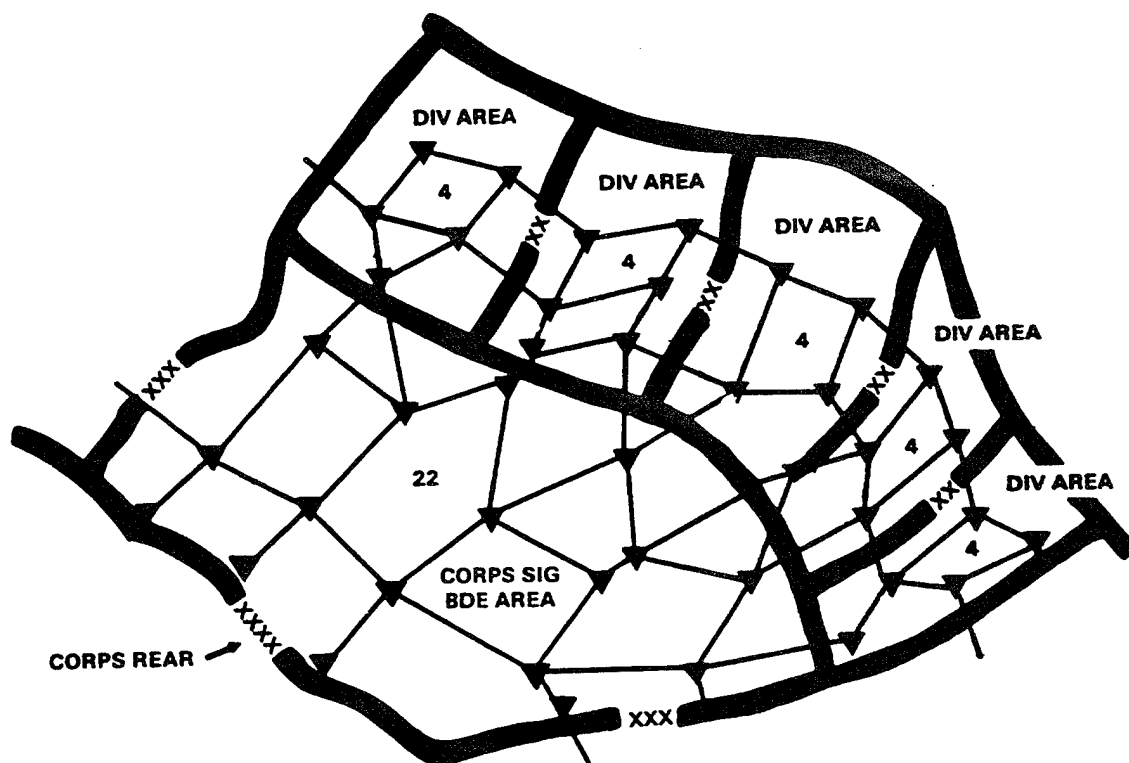
Figure 1-2. MSE deployment.

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c. MSE architecture is described by dividing it into three layers. (See Figure 1-3.) The upper layer is the network's backbone structure, consisting of interconnected NCs. The middle layer consists of large extension nodes (LENs) and small extension nodes (SENs) which provide CPs with network access. The bottom layer consists of the system's static (wire line) and mobile subscribers.

(1) The NCs serve as hubs for the entire nodal system. The LENs and SENs are branched off these NCs. The extension nodes provide voice, data, and facsimile communications to corps, division, and brigade level CPs. Each NC platoon has net radio interface (NRI) capability. The system control center (SCC) determines where the NRI can best serve the subscriber. (The current SCC is known as the SCC-1. In this manual, the SCC-1 is referred to as the SCC. During the fielding of the 7th Corps, the SCC-2 will be fielded and will completely replace the SCC-1.) The NRI can be installed in a LEN or SEN. Line of sight (LOS) ultra high frequency (UHF) radio links provide connectivity among NCs and from NCs to LENs and SENs. This furnishes all MSE subscribers with automatic switching.

(2) Mobile subscribers are equipped with mobile subscriber radiotelephone terminals (MSRTs). The mobile subscriber accesses the MSE network via a RAU. He can call any other subscriber in the network without knowing the other's location. He must simply know the other's telephone number. The mobile subscriber can talk while on the move, as long as he is within radio coverage of one of the corps deployed RAUs. While moving from one RAU's range to another, the MSRT in the user's vehicle automatically searches for the nearest RAU's beacon signal to maintain affiliation. This does not require operator intervention.

d. MSE network control is highly centralized. There are seven SCCs in a five-division corps. The SCC staff plans, deploys, maneuvers, and reconfigures the MSE corpswide network. They accomplish this mission to support the corps commander's maneuver concept. The SCC uses automated features to perform many tasks formerly done manually. Among these tasks are frequency management LOS, very high frequency (VHF), and super high frequency (SHF) key management; high-point surveys; and signal path profiling. The SCCs maintain system logistics and personnel status reports. Operational control of the MSE NCs belongs to the SCC's staff.

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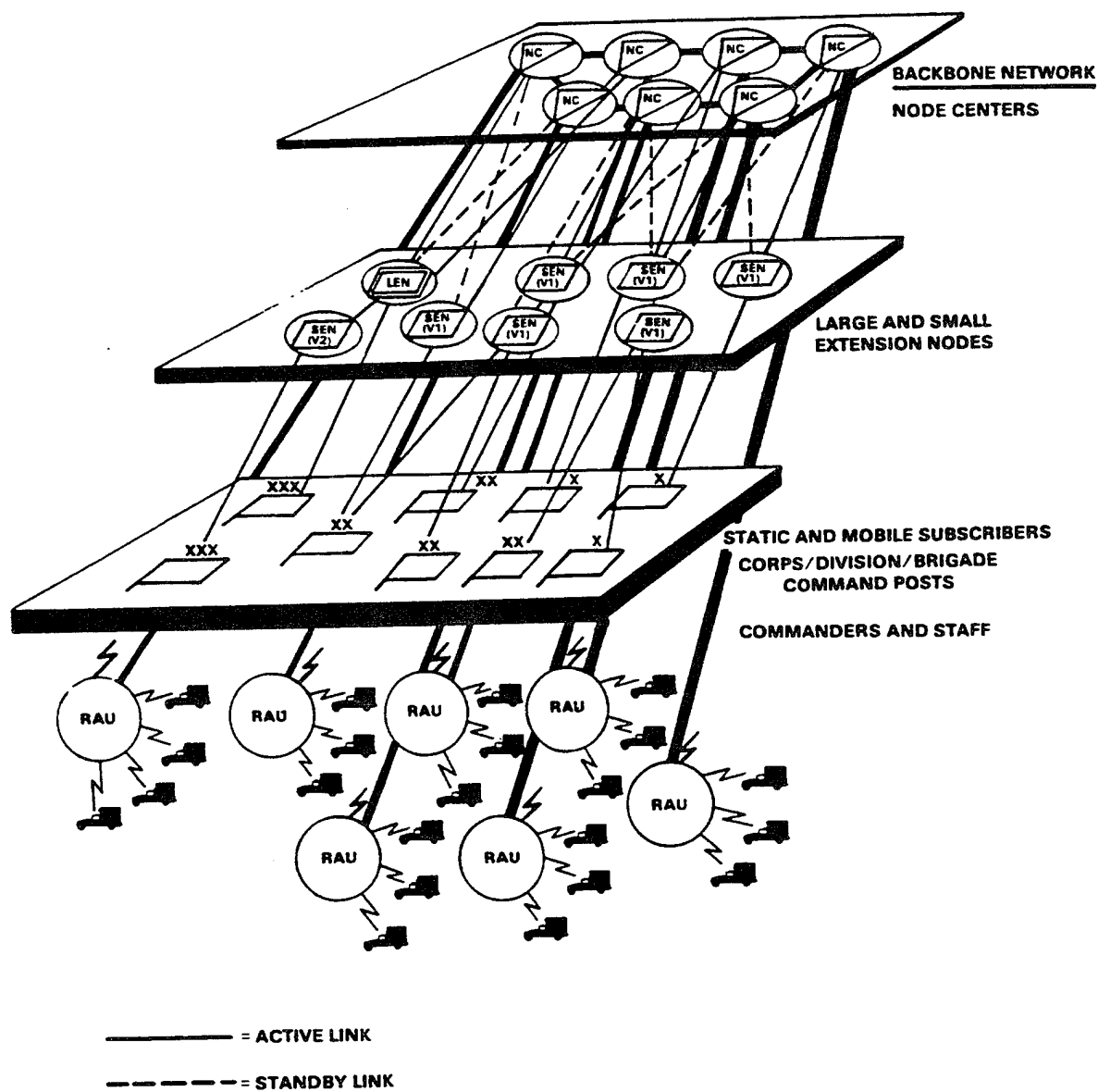
Figure 1-3. MSE architecture.

1-3. MSE System Features

a. MSE provides secure, automatic digitized voice, data, and facsimile communications to the user, whether static or mobile. Using flood search based routing eliminates the need for extensive system planning. This makes MSE more responsive to the user, easier to install, and more mobile. Because equipment is similar at every echelon, there are no problems with equipment compatibility. MSE is lighter and complies with US Air Force weight limitations. Because setup and teardown times are reduced, the signal elements can better support highly mobile users. While on the move, mobile communications service enhances C^2 for subscribers having MSRTs.

b. All MSE terminal devices are user-owned, -connected, -operated, and -maintained. MSE system and employment doctrine are designed to facilitate the user-owned and -operated concept.

1-4. MSE Site Configurations

a. NCs form a structure on which system extensions are built. (See Figure 1-4.) The LENs, SENs, and RAUs provide the subscriber with access to the corps network. They depend on the node switches (NSs) for tandem switching capability. The NC extensions depend on network strength for communications. The network is only as strong as the radio links that make up its basic structure.

b. The LEN (Figure 1-5) provides wire line service for up to 176 subscribers and usually deploys to support large CPs such as the corps support command (COSCOM) and the division support command (DISCOM). Subscribers serviced by the LEN access the MSE network via remote multiplexer combiners (RMCs) and J-1077 distribution boxes. The maximum number of subscribers connected by RMCs is 80. User-owned equipment supplies power for the RMCs. The maximum number of subscribers connected via J-1077 distribution boxes is 96. There are nine LENs in the corps, one per division signal battalion and four in the corps signal brigade.

(1) The LOS(V4) radio connects the LEN to two NCs. If one link fails, the second link provides communications connectivity. The LOS(V4) radio provides two 32-channel digital transmission groups (DTGs). Thirty channels of each link are available for subscriber use. The LOS(V4) radio can be remoted from its associated switch using an SHF radio link. Normally, the LEN should establish two active radio links going to two different nodes.

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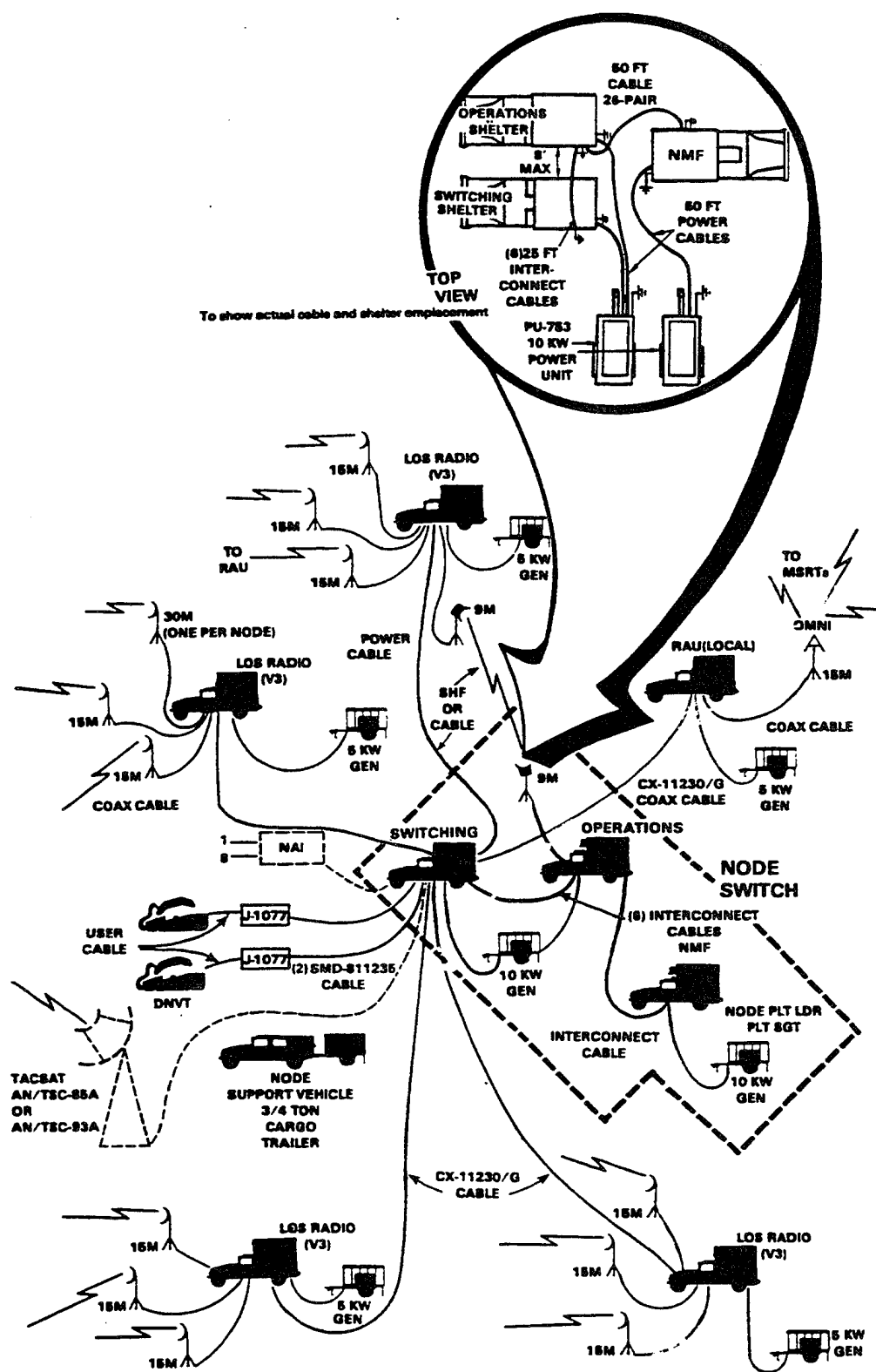
Figure 1-4. NC site configuration.
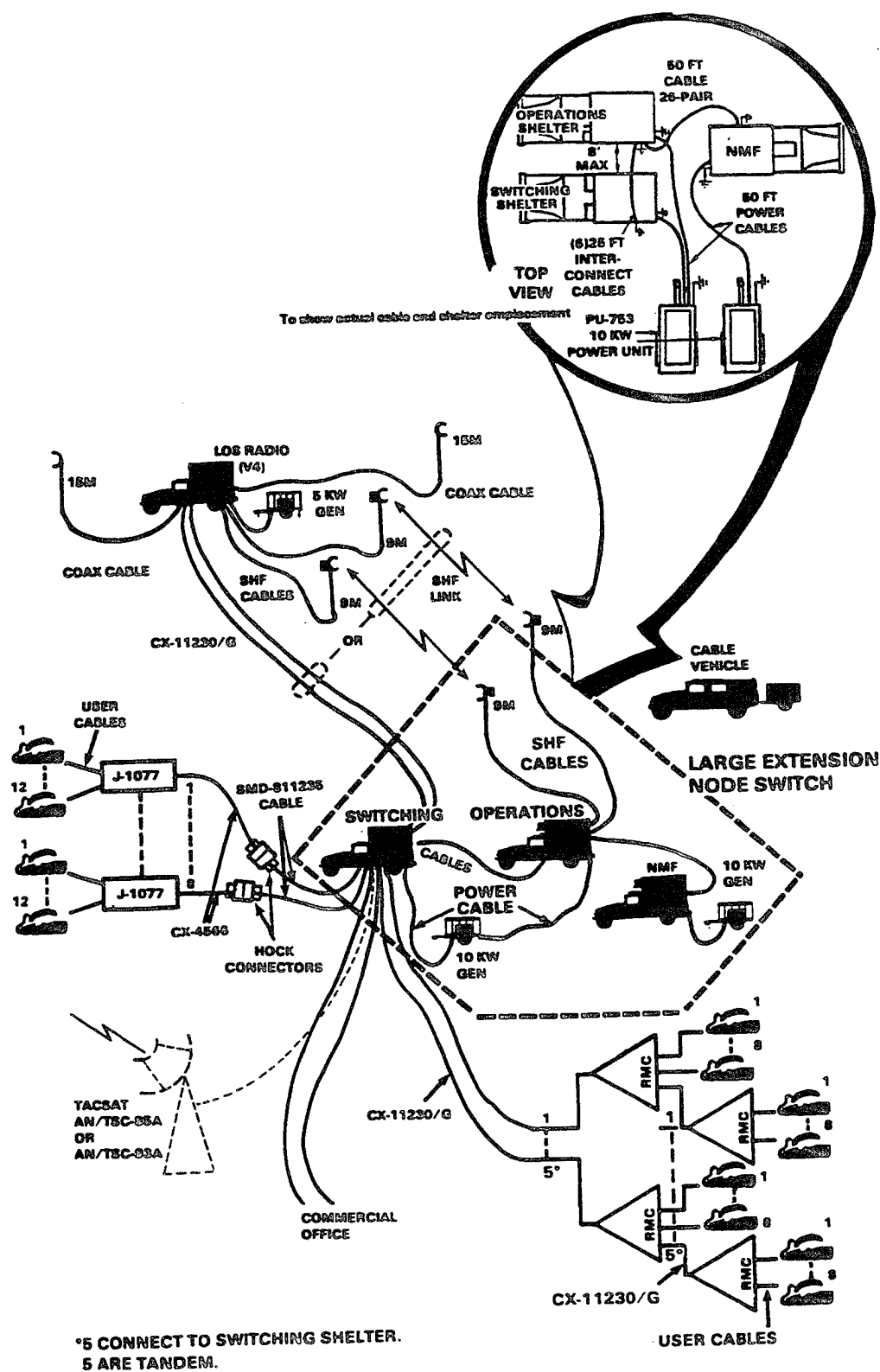
Figure 1-5. LEN configuration.

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(2) The LEN can also furnish a small extension node switch (SENS) with network access. When connected to a SEN with CX-11230/G cable, the large extension node switch (LENS) functions as a tandem switch for that SENS. In some cases, the LEN can host a local RAU. The LEN can also host an SCC (just as with an NS).

c. The SEN consists of an AN/TTC-48(V1) or (V2) switch and an AN/TRC-190(V1) LOS UHF radio system. (See Figure 1-6.) Normally, the SEN connects to an NC or to a LEN via an LOS(V1) radio. The SEN team as directed by the SCC plans for two radio links to two NCs. Because each SEN has only one 15-meter antenna mast, one link can be primary and the other alternate. Each LOS has two radio stacks and two radio frequency (RF) heads using band 1 and band 3. The SEN can be remoted from its LOS by a maximum of .4 kilometers (1/4 mile) using cable or by up to nominal 5 kilometers (3.1 miles) when using the AN/GRC-224(P) SHF radio. The SHF radio allows the switch to be close to its supported CP, yet removed from the LOS(V1) radio signature. If the SENS is within .4 kilometers (1/4 mile) of the supporting NC, it can be cabled to the NC using CX-11230/G cable.

d. Two RAUs are deployed with each NC platoon. One of the RAUs is employed locally. It is connected to the NS with CX-11230/G cable. The second RAU is remoted and is connected to an NS via LOS(V1) radio. The remoted RAU is deployed according to the subscribers' support requirements, local terrain feature constraints, and to fill in voids left by the NC's or local RAU's deployment. Areas with a greater density of customers naturally require more RAU support. The planning distance for RAU coverage is a 15-kilometer (9.3-mile) radius. Each RAU can provide support for 25 subscribers. When the RAU is on the move, the whip antenna is mounted and the digital subscriber voice terminal (DSVT) is patched to the number eight RT-1539(P)/G radio. In this way, the RAU's DSVT and RT-1539(P)/G function as an MSRT and provide the RAU with mobile communications and a CNR in the support vehicle for their FM net. Figures 1-7 and 1-8 show a remote RAU configuration and mobile subscriber connectivity.

e. The SCC assumes operational control of the MSE network elements when the network is deployed. At corps level, one SCC actively controls the network, and the second SCC is on standby status. If the primary SCC should fail, the alternate SCC assumes control of the network as directed. In this situation, one of the division SCCs will take over the alternate SCC function. Refer to FM 11-38 for more information on SCC management and control. Figure 1-9 shows the SCC.

f. There are several options for internal communications among the signal elements. The area signal company commander and the NC platoon leader have MSRTs and CNRs in their vehicles. The MSRT can be used when the platoon deploys, and it allows the NC platoon leadership to communicate with anyone in the network.
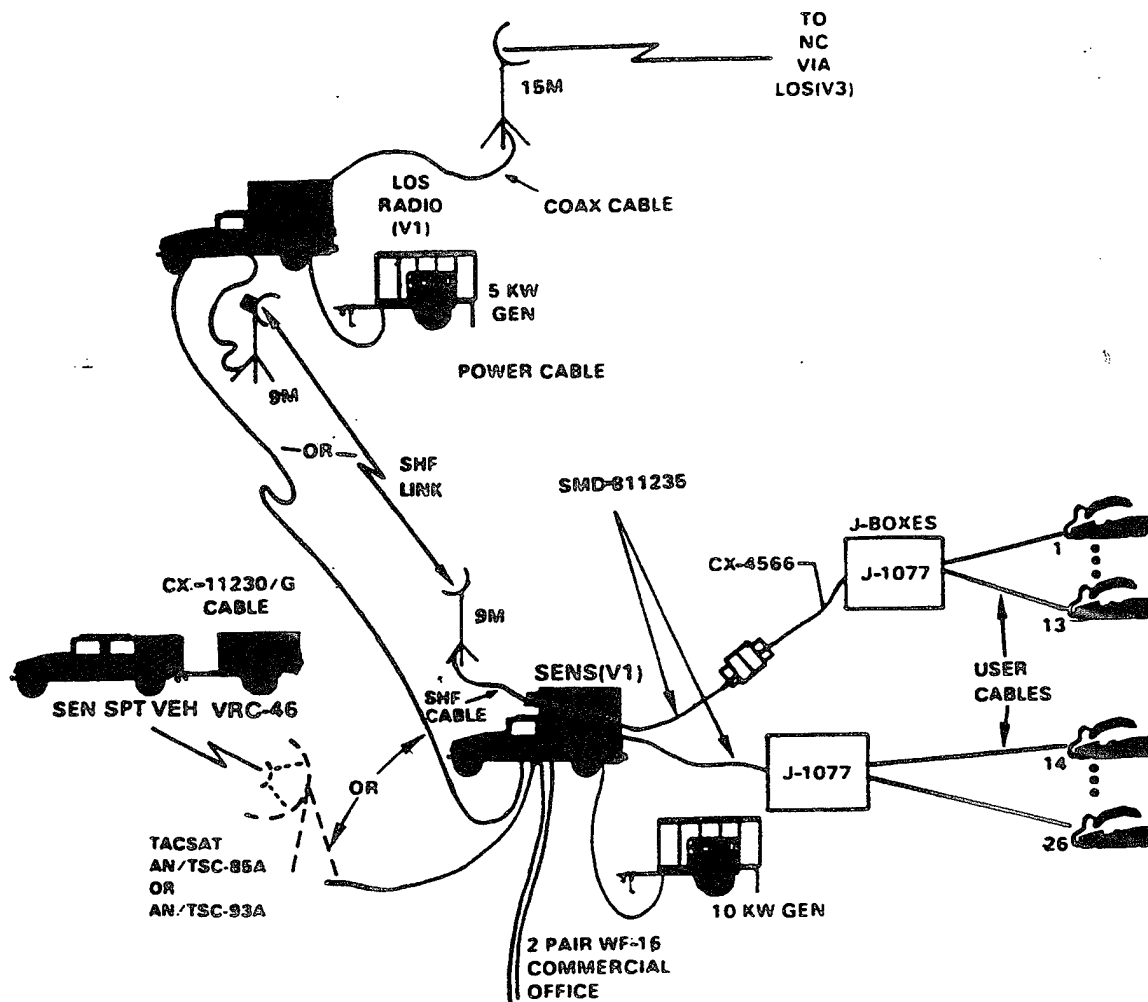
Figure 1-6. SEN (V1) configuration.

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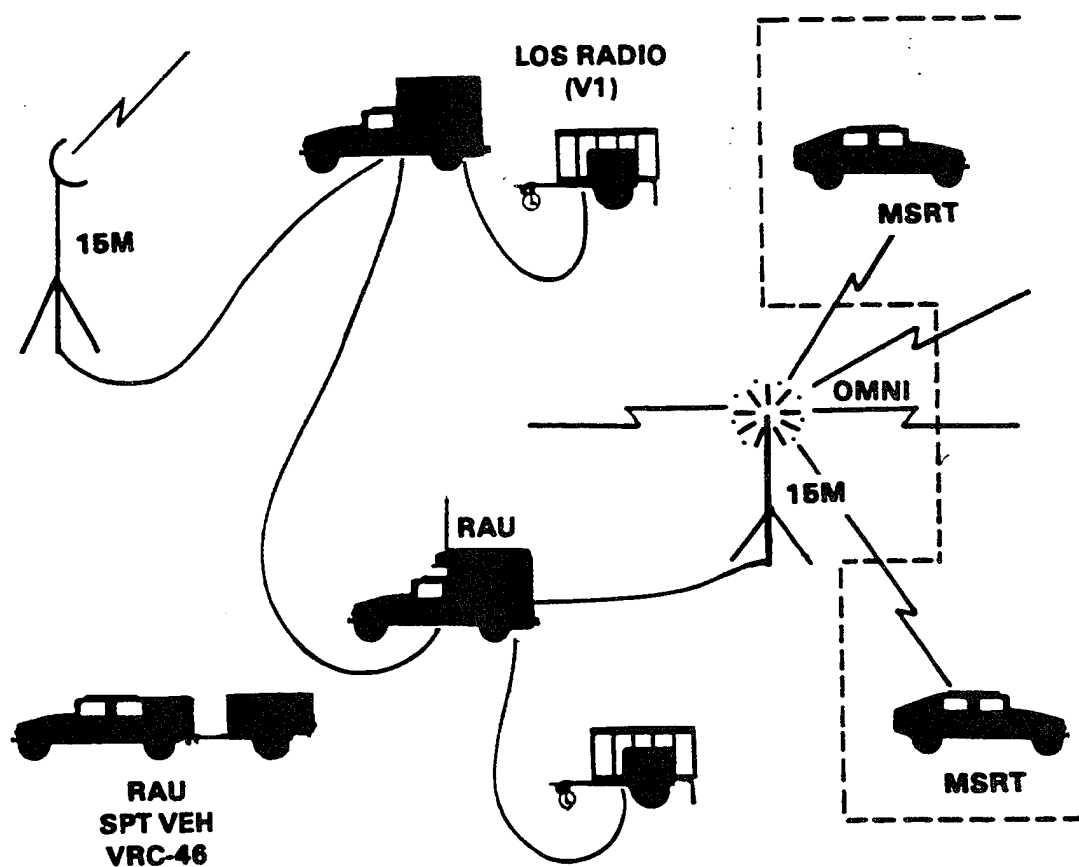
Figure 1-7. Remote RAU configuration.

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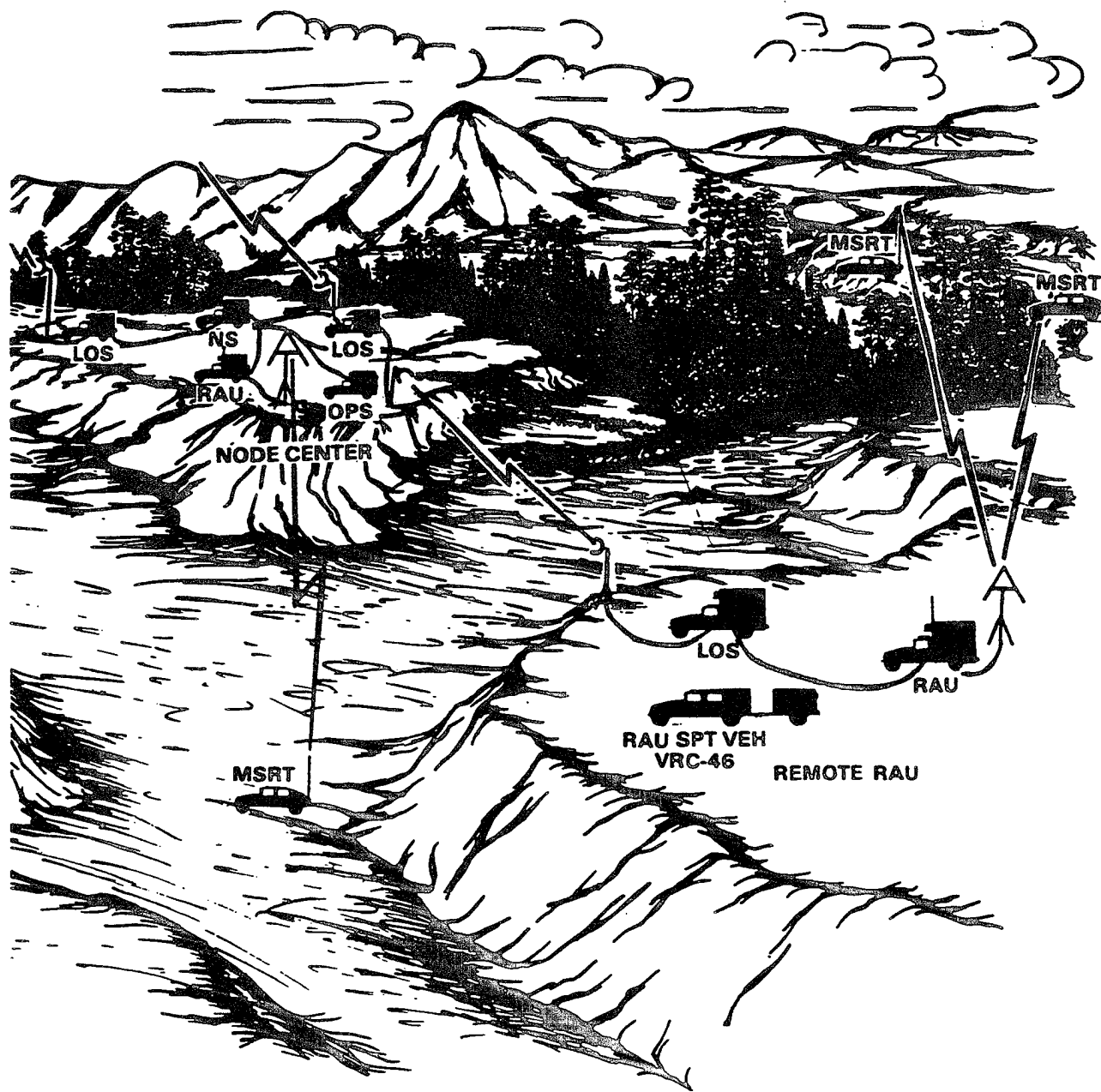
Figure 1-8. Mobile subscriber connectivity.

A.
SCC
TECHNICAL SHELTER

● Main processor and memory

● All SCC computing functions

● PU-753 10 kW diesel
generator

B.
SCC
MANAGEMENT SHELTER

● Multicolor graphic display

● Two VDU workstations

● Powered by technical
shelter
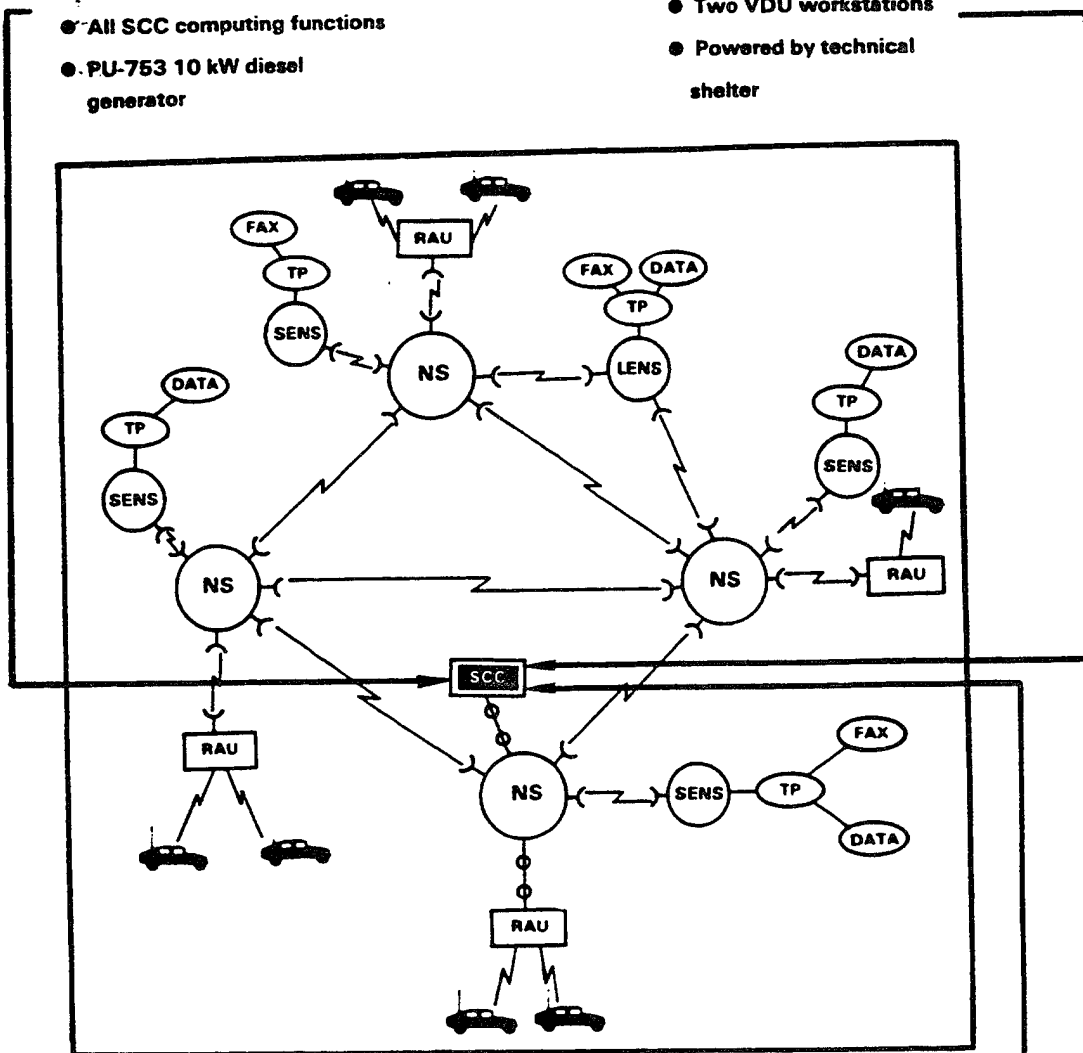
C.
SCC
PLANNING SHELTER

● Two VDU workstations

● Deployed at corps only

● PU-751 5 kW diesel
generator

Figure 1-9. System control center.

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(1) An unsecure analog engineer orderwire (EOW) is available in all LOS (AN/GRC-226) radios. The EOW permits LOS operators to communicate with one another during initial engineering or restoring failed LOS links. Once contact has been established between the two assemblages, the LOS operators change to the secure digital voice orderwire (DVOW).

(2) DVOW is transmitted over the LOS radio system. The orderwire control unit (OCU-4) or the communications modem (CM) MD-1270 is located in all manned assemblages except the node management facility (NMF) and the SCC. The OCU-4/MD-1270 allows the signal operator to talk in a secure mode with other signal elements in the network.

APPENDIX B

DESCRIPTION OF MODEL VARIABLES

DESCRIPTION OF MODEL VARIABLES

Variable	Description

1. *effect[_,_]*   **Failure effect.** This variable contains values found in the two-dimensional *effect* array (see Figure 5). The values represent the effects that shelter failures have on other shelters in an MSE platoon. The values vary from 0 to 4. The first index of the variable, i.e., the number in the first space between the brackets, is the tag value of a shelter that failed. This number corresponds to a particular row dimension of the *effect* array, and may vary from 1 to 18. The second index of the variable, i.e., the number in the second space between the brackets, is the tag value of a shelter potentially affected by the shelter failure indicated by the first index. This number corresponds to a particular column dimension of the *effect* array, and can also vary from 1 to 18. The following is a list of the possible values of the *effect[_,_]* variable and descriptions of the effects represented by the values:

Value	Effect
0	No effect. Non-linked shelter continues to relay all messages.
1	Linked shelter is operational, but capabilities are degraded. Linked shelter can relay local messages only.
2	Linked shelter is non-operational. Crew attempts to restore its radio links by aligning antennas with an operational shelter. No messages are relayed by linked shelter during this period.
3	Linked shelter is non-operational. Crew is idle while awaiting repair of shelter that failed. No messages are relayed by linked shelter during this period.
4	Failed shelter is non-operational. If possible, crew repairs shelter that failed. No messages are relayed by failed shelter during this period.

For example, *effect[9,10]* is a particular value contained in a particular cell in the *effect* array. The value represents the effect of the failure of Shelter 9 on the communication abilities of Shelter 10. In this case, the value equals 1, which means that when Shelter 9 fails, Shelter 10's communication abilities are degraded. While Shelter 9 is down, Shelter 10 can relay local traffic only.

2. *counter1[_]*   **Counter used to implement failure effects.** This variable contains values found in the one-dimensional *counter1* array. The values correspond to the tag values of shelters potentially affected by a shelter failure. The values vary from 1 to 18. The index of the variable is the tag value of a shelter that failed; the index can also vary from 1 to 18. The *counter1[_]* values are used in Task 21 as indexes for the second dimension of the *effect* array. The actual code for the *effect* array is *effect[tag-100, counter1[tag-100]]*, where *tag-100* is the tag value of the shelter that failed and *counter1[tag-100]* is the tag value of the potentially affected shelter. (See *Beginning Effect* for Task 21. This code determines how control entities are processed in the lower portion of the model and how

Variable	Description

equipment entities are processed in the upper portion of the model.)

For example, if Shelter 9 fails, *counter1[9]* starts off with a value of 1 (for Shelter 1). The code checks the *effect* array by looking at the value of *effect[9,1]*. The value is 0, so a breakdown of Shelter 9 has no effect on the relay capabilities of Shelter 1. *Counter1[9]* is incremented by 1. Then, the code checks the *effect* array by looking at the value of *effect [9,2]*. The value is 0 also. This process continues until *counter1[9]* becomes 10. At this time, the code checks the *effect* array for the value of *effect[9,10]*. It finds a value of 1. This means that when Shelter 9 fails, Shelter 10 remains operational, but with degraded capabilities, i.e., Shelter 10 can relay local traffic only. In the model, the *control entity* with tag value 110 is withdrawn from *q5* and sent to *q22*, where it remains until Shelter 9 is repaired; and the *control entity* with tag value 109 is sent to *q25*, where it remains until Shelter 9 is repaired.

3. *counter2[_]*   **Counter used to implement repair effects.** This variable contains values found in the one-dimensional *counter2* array. The values correspond to the tag values of shelters potentially affected by a shelter repair. The values vary from 1 to 18. The index of the variable is the tag value of a shelter that is repaired; the index can also vary from 1 to 18. The *counter2[_]* values are used in Task 26 as indexes for the second dimension of the *effect* array. The actual code for the *effect* array is *effect[tag-100, counter2[tag-100]]*, where *tag-100* is the tag value of the shelter that is repaired and *counter2[tag-100]* is the tag value of a shelter potentially affected by the repair. (See *Beginning Effect* for Task 26.)

For example, if Shelter 9 is repaired, *counter2[9]* starts off with a value of 1 (for Shelter 1). The code checks the *effect* array by looking at the value of *effect[9,1]*. The value is 0, so the repair of Shelter 9 has no effect on the relay capabilities of Shelter 1. *Counter2[9]* is incremented by 1. Then, the code checks the *effect* array by looking at the value of *effect [9,2]*. The value is 0 also. This process continues until *counter2[9]* becomes 10. At this time, the code checks the *effect* array for the value of *effect[9,10]*. It finds a value of 1. This means that when Shelter 9 is repaired, Shelter 10 goes from an "operating-local traffic only" mode to a "fully operational" mode. In the model, the control entity with tag value 110 is withdrawn from *q22* and sent back to *q5*; the *control entity* with tag value 109 is also sent back to *q5*.

4. *dest[_]*   **Destination.** This variable contains values found in the one-dimensional *dest* array. The values represent the effects that shelter failures have on other shelters in an MSE platoon. The values vary from 0 to 4, and have identical meanings to those used for the *effect* array. The index of the *dest* array, with possible values 1 through 18, represents the shelter being considered by the code. (See

Variable	Description

Beginning Effect for Task 61, "troubleshoot," and *Beginning Effect* for Task 21, "not operating [down]," for examples of how *dest[_]* is set. See tactical decision node following Task 5 for an example of how *dest[_]* is used to ensure that control entities are sent to appropriate queues or tasks.)

5. *eq_p1[_,_,_]* **Equipment-personnel combinations (operators).** This variable contains values found in the three-dimensional *eq_p1* array. The values correspond to six traits associated with MSE operators. For example, Trait 6 is an overall quality rating. The values associated with this trait vary from 2 to 9. The first index of the array is the tag value of the shelter that a particular operator is assigned to; the possible numbers for this index range from 1 to 18. The second index of the array is the number associated with the 12-hour work shift that a particular operator is assigned to; the possible numbers for this index are 1 and 2. The third index of the array is the number associated with an operator descriptor or trait; the possible numbers for this index range from 1 to 6. A list of the six traits and the possible variable values associated with each is shown below:

Trait no.	Trait name	Possible variable values
1	Operator PIN	PINs
2	Rank	3, 4, 5, 6, 7 (for E3 - E7)
3	Skill level	10, 20, 30, 40
4	Experience rating	1, 2, 3, 4, 5
5	Mental category	1, 2, 3, 4
6	Overall quality rating	2, 3, 4, 5, 6, 7, 8, 9

In general, this three-dimensional array of integers is used to (a) assign operators to equipment, (b) schedule work shifts for operators, and (c) store personnel identification information and descriptors that affect human performance.

6. *eq_p2[_,_,_]* **Equipment-personnel combinations (supervisors).** This variable contains values found in the three-dimensional *eq_p2* array. The values correspond to six traits associated with MSE supervisors. For example, Trait 6 is an overall quality rating. The values associated with this trait vary from 2 to 9. The first index of the array is the tag value of the shelter that a particular supervisor is assigned to; the possible numbers for this index range from 1 to 18. The second index of the array is the number associated with the 6-hour work period that a particular supervisor is assigned to; the possible numbers for this index range from 1 to 4. The third index of the array is the number associated with a supervisor descriptor or trait; the possible numbers for this index range from 1 to 6. A list of the six traits and the possible variable values associated with each is shown below:

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Variable	Description

Trait no.	Trait name	Possible variable values
1	Supervisor PIN	PINs
2	Rank	5, 6, 7 (for E5 - E7)
3	Skill level	20, 30, 40
4	Experience rating	1, 2, 3, 4, 5
5	Mental category	1, 2, 3, 4
6	Overall quality rating	2, 3, 4, 5, 6, 7, 8, 9

In general, this three-dimensional array of integers is used to (a) assign supervisors to equipment, (b) schedule work periods for supervisors, and (c) store personnel identification information and descriptors that affect human performance.

7. *eq_p1_p2[_]* **Equipment-personnel combinations (operators and supervisors).** This variable contains values found in the one-dimensional *eq_p1_p2* array. The values correspond to the sum of the overall quality rating for an operator plus the overall quality rating for a supervisor who work together in the same shelter during the same 10-minute segment. The index of the array is the tag value of the shelter involved. The possible numbers for the index range from 1 to 18. This prototype model uses the sums of overall quality ratings, plus non-research-based algorithms, to determine how many messages are relayed by specific equipment-operator-supervisor combinations during particular 10-minute segments of operation during particular shift-periods. Future algorithms should be based on research that relates human aptitude to human performance, human performance to system performance, and system performance to unit performance in order to enhance the realism of the simulation. (See *Ending Effect* for Task 91 for examples of the algorithms used.)

8. *select1[_]* **Flag used to halt "fully operational" mode.** This variable contains values found in the one-dimensional *select1* array of integers. The two possible values (0 and 1) are flag values that are used to process the control entities in the model. The index is either the shelter's *tag* value (if *select1[_]* is used in the upper portion of the model) or its *tag-100* value (if *select1[_]* is used in the lower portion of the model).

While a shelter is fully operational, the corresponding control entity is in *q5* ("fully operational"). During this period, *select1[tag-100]* equals 0. When a shelter stops operating or starts operating in a degraded mode, the corresponding control entity must be withdrawn from q5. Changing the *select1[_]* flag value from 0 to 1 initiates the withdrawal of the appropriate control entity from q5. The withdrawal takes place when *select1[tag]* is set to 1 in the upper portion of the model or when *select1[tag-100]* is set to 1 in the lower portion. (See *Beginning Effect* for Task 50, *Priority* for *q5*, *Release Condition* for Task 5, *Beginning Effect* for Task 5, and *Beginning Effect* for Task 21 to gain an understanding of what initiates the withdrawal from *q5* of a control entity representing a failed shelter and what initiates the withdrawal from *q5* of

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Variable	Description

a control entity representing a shelter affected by a shelter failure.) Basically, *select1[tag]* is set to 1 in the upper portion of the model when a shelter (represented by an equipment entity with a particular tag value) fails. And, *select1[tag-100]* is set to 1 in the lower portion of the model when a control entity (whose tag value is always 100 greater than that of the equipment entity it is paired with in the upper portion of the model) spins through Task 21 (i.e., iterates through the *effect[_,_]* array). In both of these circumstances, control entities are withdrawn from *q5* and sent to one of four destinations--depending on the operational capabilities of the corresponding shelters.

9. *select2[_]* **Flag used to halt "less than fully operational" mode.** This variable contains values found in the one-dimensional *select2* array of integers. The two possible values (0 and 1) are flag values that are used to process the control entities in the model. The array index is either the shelter's *tag* value (if *select2[_]* is used in the upper portion of the model) or its *tag-100* value (if *select2[_]* is used in the lower portion of the model).

While a shelter is less than fully operational, the corresponding control entity is either in *q22* ("operating--local traffic only"), *q24* ("not operating--idle"), or *q25* ("not operating--down"). During this period, *select2[tag-100]* equals 0 for that entity. When the associated shelter is repaired, *select2[tag]* is changed from 0 to 1 in the upper portion of model (e.g., see *Ending Effect* for Task 53). This flag releases the complementary control entity (whose tag value is always 100 greater than its partner in the upper portion) from *q25* in the lower portion of the model (e.g., see *Priority* for *q25*, *Release Condition* for Task 25, and *Beginning Effect* for Task 25). The control entity corresponding to the repaired shelter spins through Task 26 (e.g., see *Beginning Effect* for Task 26). Both types of control entities (the one representing the repaired shelter and the ones representing the shelters affected by the repair) are sent back to *q5* ("fully operational").

10. *clockin[_]* **Start time: "not operating-down".** This one-dimensional array of real numbers contains the most recent clock time when a control entity representing a particular shelter entered *q25* ("not operating--down"). The index for *clockin[_]* is *tag-100*. This variable is used only in the lower portion of model to store the clock time when a particular shelter breaks down (see *Entering Effect* for *q25*).

11. *clockout[_]* **Stop time: "not operating--down".** This one-dimensional array of real numbers contains the most recent clock time that a control entity representing a particular shelter left *q25* ("not operating--down"). The index for *clockout[_]* is *tag-100*. This variable is used only in the lower portion of model to store the clock time when a particular shelter is repaired (see *Departing Effect* for *q25*).

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Variable	Description
12. *downtime*	**Shelter downtime.** This real variable stores the latest downtime for a control entity leaving *q25*. It is computed by the following formula: *downtime = clockout[tag-100] - clockin[tag-100]*. *Downtime* is, thus, the difference between the clock time when a particular control entity left *q25* and the clock time when the entity entered *q25*.
13. *failed[_]*	**Operational status.** This one-dimensional array of integers contains flag values (0 and 1) that represent whether a particular shelter is in a failure mode (flag = 1) or a non-failure mode (flag = 0). The array index is either *tag* (if *failed[_]* is used in the upper portion of the model) or *tag-100* (if *failed[_]* is used in the lower portion). (See *Beginning Effect* for Task 50 and *Ending Effect* for Task 53 for examples of how and when the values of *failed[tag]* are changed. See *Beginning Effect* for Task 21, *Priority* for *q25*, *Release Condition* for Task 25, and *Beginning Effect* for Task 26 for examples of how *failed[tag-100]* is used in the coding logic in the lower portion of the model.)
14. *shift*	**Operator work shift.** This is an integer variable (with possible values of 1 and 2) that represents the 12-hour work shift on which the operators are currently working. When the model begins, *shift* is initialized to 1 and remains 1 until the end of the first 12-hour shift, i.e., until the *clock* = 720. (The model is run in minutes.) The variable *shift* is changed to 2 when the *clock* = 720 and remains 2 until the end of the second shift, i.e., until the *clock* = 1440. This variable is used as the 2nd index for the *eq_p1[_,_,_]* array.
15. *period*	**Supervisor work period.** This is an integer variable (with possible values of 1 through 4) that represents the 6-hour work period on which the supervisors are currently working. When the model begins, *period* is initialized to 1 and remains 1 until the end of the first, 6-hour period, i.e., until the *clock* = 360. The variable is changed to 2 when the *clock* = 360 and remains 2 until the end of the second supervisory period, i.e., until the *clock* = 720. It is changed to 3 when the *clock* = 720 and to 4 when the *clock* = 1080. The variable *period* is used as the 2nd index for the *eq_p2[_,_,_]* array.
16. *depart25*	**Departure time: *q25*.** A real variable containing the clock time for the latest departure of a control entity from *q25*. A snapshot is taken at all departures from *q25*, and the value of *depart25* is saved for further data analysis.
17. *enter25*	**Entry time: *q25*.** A real variable containing the clock time for the entry of a control entity into *q25*. A snapshot is taken at all entries into *q25*, and the value of *enter25* is saved for further data analysis.
18. *msg1*	**Message relay count (Shelter 1).** An integer variable containing the number of messages relayed by Shelter 1 during the latest 10-minute operational segment. The number is dependent upon a non-research-based algorithm relating the overall quality of an operator-supervisor pairing to the number of messages relayed by the equipment-

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Variable	Description
	operator-supervisor combination. Analogous variables (*msg2*, *msg3*, . . . *msg18*) are used for the other 17 shelters.
19. *msg1cum*	**Cumulative message relay count (Shelter 1).** An integer variable containing the cumulative number of messages relayed by Shelter 1 since the beginning of the simulation run. The cumulative total is updated at the end of each 10-minute operational segment. The formula is *msg1cum = msg1cum + msg1*. Analogous variables (*msg2cum*, *msg3cum*, . . . *msg18cum*) store cumulative data for the other 17 shelters.
20. *gen_rep[_]* *veh_mech[_]* *wire_ins[_]* *wire_t_c[_]*	These four one-dimensional arrays are not being used in the current model. If used in the future, they will contain the aptitude and experience information about personnel who are assigned to an MSE platoon but who do not work in the platoon's 18 shelters. The data will be associated with one generator repairman, one vehicle mechanic, two wire installers, and one wire system team chief.

APPENDIX C

OUTPUT OF MICRO SAINT MODEL USING AN EQUITABLE DISTRIBUTION
OF PERSONNEL BY APTITUDE FOR ENTIRE PLATOON

OUTPUT OF MICRO SAINT MODEL USING AN EQUITABLE DISTRIBUTION
OF PERSONNEL BY APTITUDE FOR ENTIRE PLATOON

run	clock	msg1cum	msg2cum	msg3cum	msg4cum	msg5cum
1	1440.10	1320.00	840	840	640	670
2	1440.10	960.00	870	870	680	760
3	1440.10	1240.00	870	840	660	800

TABLE 3

Data1.res output file: equitable distribution of personnel
by aptitude

msg6cum	msg7cum	msg8cum	msg9cum	msg10cum	msg11cum	msg12cum
590	510	750	870	930	1000	870
900	750	780	1110	1110	1230	990
830	780	840	1080	150	1020	900

msg13cum	msg14cum	msg15cum	msg16cum	msg17cum	msg18cum
180	180	1050	950	1020	1320
750	780	1080	1020	750	950
1230	270	930	820	960	1170

Trigger
end of run
end of run
end of run

run	clock	crew[1]	msg1cum	crew[2]	msg2cum	crew[3]
1	0.00	0	0.00	0	0	0
1	360.00	9	520.00	18	210	18
1	720.00	9	800.00	18	390	18
1	1080.00	10	920.00	17	510	17
1	1440.00	10	1320.00	17	840	17
2	0.00	0	0.00	0	0	0
2	360.00	9	160.00	18	150	18
2	720.00	9	440.00	18	420	18
2	1080.00	10	760.00	17	660	17
2	1440.00	10	960.00	17	870	17
3	0.00	0	0.00	0	0	0
3	360.00	9	280.00	18	210	18
3	720.00	9	560.00	18	420	18
3	1080.00	10	920.00	17	630	17
3	1440.00	10	1240.00	17	870	17

Table 4.

Data 2.res output file: equitable distribution of personnel by aptitude

msg3cum	crew[4]	msg4cum	crew[5]	msg5cum	crew[6]	msg6cum
0	0	0	0	0	0	0
210	16	160	16	120	16	140
420	12	340	13	330	13	350
540	17	520	16	430	14	440
840	13	640	13	670	11	590
0	0	0	0	0	0	0
150	16	140	16	100	16	180
420	12	350	13	310	13	450
690	17	470	16	430	14	720
870	13	680	13	760	11	900
0	0	0	0	0	0	0
210	16	100	16	140	16	140
420	12	310	13	380	13	410
600	17	450	16	560	14	620
840	13	660	13	800	11	830

Table 4 (continued)

crew[7]	msg7cum	crew[8]	msg8cum	crew[9]	msg9cum	crew[10]
0	0	0	0	0	0	0
14	240	13	210	13	270	15
12	450	12	390	12	570	14
14	510	13	510	13	720	12
14	510	12	750	12	870	11
0	0	0	0	0	0	0
14	150	13	150	13	270	15
12	360	12	390	12	600	14
14	630	13	630	13	840	12
12	750	12	780	12	1110	11
0	0	0	0	0	0	0
14	210	13	180	13	180	15
12	420	12	420	12	510	15
14	600	13	600	13	840	15
12	780	12	840	12	1080	15

Table 4 (continued)

msg10cum	crew[11]	msg11cum	crew[12]	msg12cum	crew[13]	msg13cum
0	0	0	0	0	0	0
300	10	320	12	240	13	180
600	11	410	12	360	13	180
750	10	730	14	570	13	180
930	11	1000	14	870	13	180
0	0	0	0	0	0	0
240	10	440	12	240	13	180
570	11	770	12	570	12	390
840	10	1050	14	810	12	570
1110	11	1230	14	990	11	750
0	0	0	0	0	0	0
150	10	160	12	120	13	330
150	11	400	12	360	12	540
150	10	720	14	630	12	750
150	11	1020	14	900	11	1230

Table 4 (continued)

crew[14]	msg14cum	crew[15]	msg15cum	crew[16]	msg16cum	crew[17]
0	0	0	0	0	0	0
15	180	14	300	14	300	12
15	180	11	510	11	510	12
15	180	14	720	16	650	13
15	180	11	1050	13	950	13
0	0	0	0	0	0	0
15	240	14	270	14	270	12
13	450	11	630	11	660	12
14	600	14	900	16	840	13
12	780	11	1080	13	1020	13
0	0	0	0	0	0	0
15	270	14	210	14	180	12
15	270	11	450	11	420	12
15	270	14	660	16	580	13
15	270	11	930	13	820	13

Table 4 (continued)

msg17cum	crew[18]	msg18cum	Trigger
0	0	0	clock
330	9	440	clock
630	10	840	clock
780	10	1080	clock
1020	11	1320	clock
0	0	0	clock
240	9	280	clock
450	10	600	clock
630	10	800	clock
750	11	950	clock
0	0	0	clock
180	9	240	clock
390	10	520	clock
630	10	840	clock
960	11	1170	clock

Table 4 (continued)

run	clock	tag	Trigger
1	10.00	109	enter 25
1	10.00	110	enter 25
1	10.00	113	enter 25
1	20.00	103	enter 25
1	20.00	118	enter 25
1	74.17	112	enter 25
1	80.44	115	enter 25
1	80.63	108	enter 25
1	80.63	114	enter 25
1	84.40	109	enter 25
1	90.63	101	enter 25
1	90.63	102	enter 25
1	90.63	105	enter 25
1	90.63	106	enter 25
1	95.42	117	enter 25
1	144.12	111	enter 25
1	152.82	114	enter 25
1	155.28	104	enter 25
1	155.28	107	enter 25
1	155.28	102	enter 25
1	161.99	116	enter 25
1	186.10	117	enter 25
1	197.12	101	enter 25
1	201.52	113	enter 25
1	210.76	111	enter 25
1	213.52	109	enter 25
1	213.80	108	enter 25
1	214.26	114	enter 25
1	221.45	106	enter 25
1	221.66	107	enter 25
1	222.13	104	enter 25
1	222.80	102	enter 25
1	230.74	115	enter 25
1	269.26	118	enter 25
1	276.74	112	enter 25
1	281.66	101	enter 25
1	283.78	110	enter 25
1	285.43	106	enter 25
1	285.81	107	enter 25
1	291.58	105	enter 25
1	292.09	114	enter 25
1	292.94	108	enter 25
1	295.15	103	enter 25

Table 5.
Data3.res output file: equitable distribution of personnel by aptitude

1	313.33	115	enter 25
1	352.20	112	enter 25
1	353.62	107	enter 25
1	362.78	103	enter 25
1	365.99	117	enter 25
1	368.09	110	enter 25
1	379.10	115	enter 25
1	423.03	107	enter 25
1	426.53	111	enter 25
1	426.53	112	enter 25
1	435.36	102	enter 25
1	457.83	116	enter 25
1	457.83	115	enter 25
1	465.73	117	enter 25
1	477.92	110	enter 25
1	496.87	111	enter 25
1	498.66	107	enter 25
1	499.87	101	enter 25
1	504.71	105	enter 25
1	507.04	104	enter 25
1	524.94	103	enter 25
1	524.94	102	enter 25
1	539.04	109	enter 25
1	539.27	118	enter 25
1	553.07	116	enter 25
1	559.54	112	enter 25
1	574.43	105	enter 25
1	575.21	101	enter 25
1	582.35	107	enter 25
1	589.64	104	enter 25
1	592.13	103	enter 25
1	621.08	118	enter 25
1	621.13	115	enter 25
1	622.66	110	enter 25
1	632.05	111	enter 25
1	643.09	105	enter 25
1	657.20	101	enter 25
1	659.64	103	enter 25
1	688.16	116	enter 25
1	690.77	109	enter 25
1	698.52	112	enter 25
1	703.16	117	enter 25
1	703.16	118	enter 25
1	716.87	105	enter 25
1	728.44	102	enter 25

Table 5 (continued)

68

1	760.07	110	enter 25
1	765.76	115	enter 25
1	784.21	118	enter 25
1	784.30	111	enter 25
1	802.45	104	enter 25
1	804.01	102	enter 25
1	816.30	109	enter 25
1	841.37	115	enter 25
1	843.40	112	enter 25
1	858.62	118	enter 25
1	858.76	107	enter 25
1	859.00	103	enter 25
1	874.25	104	enter 25
1	880.62	110	enter 25
1	909.99	116	enter 25
1	912.16	111	enter 25
1	922.42	106	enter 25
1	930.96	102	enter 25
1	931.43	118	enter 25
1	964.32	110	enter 25
1	983.96	112	enter 25
1	989.40	103	enter 25
1	998.99	116	enter 25
1	1008.62	118	enter 25
1	1030.03	109	enter 25
1	1049.74	111	enter 25
1	1052.45	105	enter 25
1	1054.77	104	enter 25
1	1059.33	106	enter 25
1	1059.80	103	enter 25
1	1093.41	116	enter 25
1	1094.35	117	enter 25
1	1107.31	110	enter 25
1	1122.97	106	enter 25
1	1125.83	101	enter 25
1	1136.87	104	enter 25
1	1137.64	108	enter 25
1	1142.90	111	enter 25
1	1145.19	103	enter 25
1	1174.37	117	enter 25
1	1177.11	110	enter 25
1	1192.24	106	enter 25
1	1200.97	116	enter 25
1	1208.24	104	enter 25
1	1210.75	112	enter 25

Table 5 (continued)

69

1	1210.73	112	enter 25
1	1211.29	105	enter 25
1	1217.58	108	enter 25
1	1231.06	101	enter 25
1	1248.43	118	enter 25
1	1256.74	110	enter 25
1	1264.26	106	enter 25
1	1274.30	115	enter 25
1	1281.41	102	enter 25
1	1292.28	108	enter 25
1	1292.32	105	enter 25
1	1303.55	111	enter 25
1	1315.79	109	enter 25
1	1322.88	118	enter 25
1	1328.64	106	enter 25
1	1329.45	101	enter 25
1	1341.04	103	enter 25
1	1359.05	115	enter 25
1	1361.17	105	enter 25
1	1380.06	108	enter 25
1	1392.48	112	enter 25
1	1399.76	106	enter 25
1	1403.60	110	enter 25
1	1405.24	102	enter 25
1	1409.27	118	enter 25
1	1423.38	115	enter 25
2	10.00	103	enter 25
2	10.00	104	enter 25
2	10.00	111	enter 25
2	10.00	112	enter 25
2	10.00	114	enter 25
2	10.00	117	enter 25
2	48.22	109	enter 25
2	71.51	104	enter 25
2	75.56	111	enter 25
2	82.21	115	enter 25
2	83.52	103	enter 25
2	91.68	117	enter 25
2	91.68	118	enter 25
2	119.17	114	enter 25
2	136.64	110	enter 25
2	136.64	109	enter 25
2	137.74	112	enter 25
2	140.76	104	enter 25
2	156.63	101	enter 25

Table 5 (continued)

70

2	156.63	107	enter 25
2	165.48	116	enter 25
2	165.48	115	enter 25
2	166.63	102	enter 25
2	166.63	106	enter 25
2	166.63	103	enter 25
2	170.73	118	enter 25
2	194.07	113	enter 25
2	194.07	114	enter 25
2	215.46	104	enter 25
2	216.59	107	enter 25
2	217.49	110	enter 25
2	225.84	105	enter 25
2	225.84	103	enter 25
2	232.46	117	enter 25
2	251.62	112	enter 25
2	253.87	116	enter 25
2	266.94	106	enter 25
2	271.36	114	enter 25
2	282.68	109	enter 25
2	292.21	104	enter 25
2	293.45	102	enter 25
2	319.36	117	enter 25
2	320.80	115	enter 25
2	327.68	111	enter 25
2	333.03	114	enter 25
2	343.05	106	enter 25
2	362.46	109	enter 25
2	364.04	101	enter 25
2	365.16	103	enter 25
2	386.41	112	enter 25
2	396.72	118	enter 25
2	401.08	114	enter 25
2	430.49	106	enter 25
2	431.79	116	enter 25
2	442.44	104	enter 25
2	442.87	109	enter 25
2	445.59	105	enter 25
2	445.88	101	enter 25
2	448.00	108	enter 25
2	448.00	103	enter 25
2	474.99	111	enter 25
2	484.10	113	enter 25
2	484.16	118	enter 25
2	501.68	106	enter 25

Table 5 (continued)

71

2	516.97	108	enter 25
2	517.72	102	enter 25
2	518.12	116	enter 25
2	540.28	110	enter 25
2	551.43	117	enter 25
2	573.94	114	enter 25
2	578.38	101	enter 25
2	579.86	111	enter 25
2	592.49	107	enter 25
2	600.24	104	enter 25
2	600.58	106	enter 25
2	602.49	105	enter 25
2	604.15	103	enter 25
2	611.89	118	enter 25
2	617.61	116	enter 25
2	631.98	113	enter 25
2	644.08	110	enter 25
2	653.45	108	enter 25
2	663.59	111	enter 25
2	672.57	102	enter 25
2	683.58	118	enter 25
2	697.62	116	enter 25
2	701.09	114	enter 25
2	714.91	108	enter 25
2	725.71	112	enter 25
2	732.89	110	enter 25
2	734.47	101	enter 25
2	738.95	104	enter 25
2	744.91	106	enter 25
2	746.98	107	enter 25
2	751.94	102	enter 25
2	754.99	113	enter 25
2	758.40	117	enter 25
2	784.91	112	enter 25
2	789.13	116	enter 25
2	803.56	104	enter 25
2	811.37	108	enter 25
2	811.47	101	enter 25
2	818.98	107	enter 25
2	820.87	102	enter 25
2	822.91	114	enter 25
2	823.51	117	enter 25
2	823.67	110	enter 25
2	869.29	112	enter 25
2	872.85	104	enter 25

Table 5 (continued)

2	872.85	104	enter 25
2	879.96	113	enter 25
2	885.98	102	enter 25
2	893.78	116	enter 25
2	907.39	117	enter 25
2	911.62	110	enter 25
2	938.99	111	enter 25
2	948.69	105	enter 25
2	952.51	104	enter 25
2	952.61	101	enter 25
2	954.98	115	enter 25
2	960.47	114	enter 25
2	961.31	118	enter 25
2	968.02	109	enter 25
2	977.21	102	enter 25
2	999.35	112	enter 25
2	1013.49	105	enter 25
2	1014.26	104	enter 25
2	1016.96	116	enter 25
2	1031.54	113	enter 25
2	1036.61	117	enter 25
2	1039.24	110	enter 25
2	1042.98	108	enter 25
2	1056.49	107	enter 25
2	1056.97	103	enter 25
2	1071.18	112	enter 25
2	1079.44	116	enter 25
2	1086.17	104	enter 25
2	1086.99	105	enter 25
2	1097.28	113	enter 25
2	1105.99	117	enter 25
2	1108.03	109	enter 25
2	1119.78	103	enter 25
2	1150.85	112	enter 25
2	1156.62	105	enter 25
2	1159.74	115	enter 25
2	1163.93	104	enter 25
2	1165.83	118	enter 25
2	1186.15	107	enter 25
2	1187.16	110	enter 25
2	1187.93	106	enter 25
2	1189.34	113	enter 25
2	1190.06	101	enter 25
2	1199.85	103	enter 25
2	1229.31	105	enter 25

Table 5 (continued)

73

2	1230.58	118	enter 25
2	1235.51	111	enter 25
2	1235.57	116	enter 25
2	1246.22	104	enter 25
2	1260.53	102	enter 25
2	1260.56	114	enter 25
2	1287.45	110	enter 25
2	1298.33	115	enter 25
2	1310.93	111	enter 25
2	1312.63	117	enter 25
2	1321.50	104	enter 25
2	1325.28	114	enter 25
2	1335.10	107	enter 25
2	1335.64	102	enter 25
2	1357.71	109	enter 25
2	1366.59	112	enter 25
2	1372.56	118	enter 25
2	1378.93	116	enter 25
2	1387.60	104	enter 25
2	1388.14	113	enter 25
2	1401.75	101	enter 25
2	1403.65	108	enter 25
2	1418.34	102	enter 25
2	1427.05	110	enter 25
3	10.00	105	enter 25
3	10.00	106	enter 25
3	10.00	108	enter 25
3	10.00	109	enter 25
3	10.00	111	enter 25
3	10.00	117	enter 25
3	10.00	118	enter 25
3	20.00	103	enter 25
3	20.00	116	enter 25
3	72.25	114	enter 25
3	78.73	110	enter 25
3	79.63	112	enter 25
3	83.54	118	enter 25
3	88.64	101	enter 25
3	88.64	102	enter 25
3	88.64	104	enter 25
3	134.17	115	enter 25
3	147.06	105	enter 25
3	149.27	117	enter 25
3	150.51	109	enter 25
3	155.04	106	enter 25

Table 5 (continued)

3	156.07	107	enter 25
3	156.76	108	enter 25
3	165.52	104	enter 25
3	166.07	103	enter 25
3	178.24	114	enter 25
3	204.72	111	enter 25
3	209.00	116	enter 25
3	213.09	110	enter 25
3	216.94	105	enter 25
3	217.16	106	enter 25
3	220.90	117	enter 25
3	236.68	109	enter 25
3	236.68	103	enter 25
3	260.52	113	enter 25
3	260.52	114	enter 25
3	261.98	112	enter 25
3	283.98	116	enter 25
3	288.33	118	enter 25
3	296.56	106	enter 25
3	301.50	105	enter 25
3	309.51	102	enter 25
3	320.14	111	enter 25
3	343.17	113	enter 25
3	348.22	115	enter 25
3	354.84	118	enter 25
3	360.27	106	enter 25
3	365.76	109	enter 25
3	370.71	108	enter 25
3	377.65	104	enter 25
3	380.36	103	enter 25
3	400.26	111	enter 25
3	413.12	116	enter 25
3	415.40	117	enter 25
3	430.24	113	enter 25
3	436.50	109	enter 25
3	437.55	106	enter 25
3	445.60	105	enter 25
3	446.87	108	enter 25
3	447.74	104	enter 25
3	454.69	107	enter 25
3	455.05	102	enter 25
3	455.05	103	enter 25
3	463.35	112	enter 25
3	498.07	115	enter 25
3	500.77	113	enter 25

Table 5 (continued)

75

3	510.43	109	enter 25
3	512.42	117	enter 25
3	514.05	104	enter 25
3	515.26	105	enter 25
3	516.01	108	enter 25
3	527.00	103	enter 25
3	556.73	112	enter 25
3	560.74	116	enter 25
3	572.90	118	enter 25
3	580.42	113	enter 25
3	606.79	105	enter 25
3	606.98	106	enter 25
3	612.29	102	enter 25
3	621.08	109	enter 25
3	628.00	116	enter 25
3	637.72	112	enter 25
3	641.17	117	enter 25
3	646.81	113	enter 25
3	677.67	101	enter 25
3	680.63	103	enter 25
3	703.27	111	enter 25
3	712.97	109	enter 25
3	715.46	113	enter 25
3	717.34	115	enter 25
3	726.02	118	enter 25
3	755.19	102	enter 25
3	775.15	116	enter 25
3	784.13	111	enter 25
3	784.72	109	enter 25
3	792.82	118	enter 25
3	808.05	113	enter 25
3	821.64	107	enter 25
3	827.56	105	enter 25
3	831.45	102	enter 25
3	849.80	109	enter 25
3	855.09	115	enter 25
3	861.88	112	enter 25
3	871.31	117	enter 25
3	893.20	113	enter 25
3	897.91	108	enter 25
3	904.85	107	enter 25
3	905.19	103	enter 25
3	926.25	111	enter 25
3	954.26	115	enter 25

Table 5 (continued)

3	956.06	118	enter 25
3	962.77	113	enter 25
3	964.72	109	enter 25
3	972.23	101	enter 25
3	978.13	105	enter 25
3	986.49	106	enter 25
3	989.47	102	enter 25
3	994.29	112	enter 25
3	1021.73	116	enter 25
3	1031.43	113	enter 25
3	1038.00	118	enter 25
3	1056.49	109	enter 25
3	1065.54	107	enter 25
3	1071.65	102	enter 25
3	1075.39	112	enter 25
3	1097.75	113	enter 25
3	1105.38	118	enter 25
3	1112.36	115	enter 25
3	1125.93	101	enter 25
3	1130.39	105	enter 25
3	1136.82	104	enter 25
3	1139.31	109	enter 25
3	1144.83	102	enter 25
3	1145.75	112	enter 25
3	1169.36	113	enter 25
3	1179.09	116	enter 25
3	1188.89	118	enter 25
3	1194.74	105	enter 25
3	1203.96	108	enter 25
3	1206.04	106	enter 25
3	1207.57	109	enter 25
3	1213.94	103	enter 25
3	1257.10	115	enter 25
3	1264.82	112	enter 25
3	1269.91	108	enter 25
3	1277.09	106	enter 25
3	1281.18	105	enter 25
3	1291.23	103	enter 25
3	1298.57	109	enter 25
3	1320.59	117	enter 25
3	1326.79	115	enter 25
3	1342.88	113	enter 25
3	1344.54	111	enter 25
3	1349.88	107	enter 25
3	1354.93	109	enter 25

Table 5 (continued)

3	1355.86	102	enter 25
3	1385.59	118	enter 25
3	1407.90	111	enter 25
3	1414.48	115	enter 25
3	1416.18	107	enter 25
3	1425.84	104	enter 25
3	1427.80	101	enter 25
3	1429.51	108	enter 25
3	1431.91	106	enter 25
3	1431.92	109	enter 25
3	1438.99	102	enter 25

Table 5 (continued)

run	clock	tag	in_q25	out_q25	downtime	
1	63.77	110	10.00	63.77	53.77	
1	70.63	103	20.00	70.63	50.63	
1	72.63	113	10.00	72.63	62.63	
1	74.40	109	10.00	74.40	64.40	
1	85.42	118	20.00	85.42	65.42	
1	134.12	112	74.17	134.12	59.95	
1	136.16	109	84.40	136.16	51.75	
1	136.28	108	80.63	136.28	55.65	
1	141.99	115	80.44	141.99	61.55	
1	142.82	114	80.63	142.82	62.20	
1	145.28	102	90.63	145.28	54.65	
1	146.10	117	95.42	146.10	50.68	
1	151.70	105	90.63	151.70	61.07	
1	153.93	106	90.63	153.93	63.30	
1	157.12	101	90.63	157.12	66.50	
1	200.76	111	144.12	200.76	56.65	
1	204.26	114	152.82	204.26	51.44	
1	211.66	107	155.28	211.66	56.39	
1	212.13	104	155.28	212.13	56.85	
1	212.80	102	155.28	212.80	57.52	
1	220.74	116	161.99	220.74	58.75	
1	249.26	117	186.10	249.26	63.16	
1	251.66	101	197.12	251.66	54.54	
1	256.74	111	210.76	256.74	45.98	
1	263.23	113	201.52	263.23	61.70	
1	272.09	114	214.26	272.09	57.83	
1	272.94	108	213.80	272.94	59.14	
1	274.41	109	213.52	274.41	60.88	
1	275.43	106	221.45	275.43	53.98	
1	275.81	107	221.66	275.81	54.15	
1	277.25	104	222.13	277.25	55.12	
1	285.15	102	222.80	285.15	62.36	
1	293.33	115	230.74	293.33	62.59	
1	335.99	118	269.26	335.99	66.73	
1	337.71	101	281.66	337.71	56.05	
1	338.09	110	283.78	338.09	54.31	
1	342.20	112	276.74	342.20	65.46	
1	343.57	106	285.43	343.57	58.14	
1	343.62	107	285.81	343.62	57.81	
1	352.55	105	291.58	352.55	60.97	
1	352.78	103	295.15	352.78	57.63	
1	355.23	108	292.94	355.23	62.29	
1	369.10	115	313.33	369.10	55.77	

Table 6.
Data4.res output file: equitable distribution of personnel by aptitude

Trigger
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Table 6 (continued)

1	413.03	107	353.62	413.03	59.40
1	416.53	112	352.20	416.53	64.33
1	425.36	103	362.78	425.36	62.58
1	425.73	117	365.99	425.73	59.74
1	427.92	110	368.09	427.92	59.83
1	447.83	115	379.10	447.83	68.73
1	478.66	107	423.03	478.66	55.63
1	484.49	112	426.53	484.49	57.96
1	486.87	111	426.53	486.87	60.34
1	494.94	102	435.36	494.94	59.58
1	521.94	115	457.83	521.94	64.11
1	523.07	116	457.83	523.07	65.23
1	529.27	117	465.73	529.27	63.54
1	538.41	110	477.92	538.41	60.49
1	551.91	111	496.87	551.91	55.04
1	555.21	101	499.87	555.21	55.34
1	562.35	107	498.66	562.35	63.69
1	564.43	105	504.71	564.43	59.72
1	569.64	104	507.04	569.64	62.61
1	582.13	103	524.94	582.13	57.18
1	591.45	102	524.94	591.45	66.51
1	593.29	109	539.04	593.29	54.25
1	601.08	118	539.27	601.08	61.81
1	612.26	116	553.07	612.26	59.19
1	629.67	112	559.54	629.67	70.13
1	633.09	105	574.43	633.09	58.66
1	637.20	101	575.21	637.20	61.98
1	639.39	107	582.35	639.39	57.05
1	647.39	104	589.64	647.39	57.75
1	649.64	103	592.13	649.64	57.51
1	677.03	115	621.13	677.03	55.90
1	680.13	110	622.66	680.13	57.47
1	683.16	118	621.08	683.16	62.08
1	690.90	111	632.05	690.90	58.85
1	696.87	105	643.09	696.87	53.78
1	709.75	101	657.20	709.75	52.56
1	719.11	103	659.64	719.11	59.47
1	746.89	116	688.16	746.89	58.73
1	750.70	109	690.77	750.70	59.93
1	761.92	112	698.52	761.92	63.40
1	764.21	118	703.16	764.21	61.04
1	767.34	105	716.87	767.34	50.47
1	774.13	117	703.16	774.13	70.97
1	794.01	102	728.44	794.01	65.58
1	815.67	110	760.07	815.67	55.60

Table 6 (continued)

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Table 6 (continued)

1	831.37	115	765.76	831.37	65.61
1	835.78	111	784.30	835.78	51.48
1	838.62	118	784.21	838.62	54.42
1	858.33	102	804.01	858.33	54.31
1	864.25	104	802.45	864.25	61.81
1	871.25	109	816.30	871.25	54.95
1	899.79	112	843.40	899.79	56.38
1	908.87	115	841.37	908.87	67.49
1	921.43	118	858.62	921.43	62.80
1	921.63	103	859.00	921.63	62.63
1	934.37	104	874.25	934.37	60.11
1	944.32	110	880.62	944.32	63.70
1	966.34	111	912.16	966.34	54.18
1	968.99	116	909.99	968.99	59.00
1	988.72	102	930.96	988.72	57.77
1	988.93	106	922.42	988.93	66.51
1	998.62	118	931.43	998.62	67.19
1	1019.40	110	964.32	1019.40	55.08
1	1037.36	112	983.96	1037.36	53.40
1	1049.80	103	989.40	1049.80	60.40
1	1063.41	116	998.99	1063.41	64.43
1	1074.43	118	1008.62	1074.43	65.81
1	1097.94	109	1030.03	1097.94	67.91
1	1112.90	111	1049.74	1112.90	63.16
1	1112.97	106	1059.33	1112.97	53.64
1	1114.39	105	1052.45	1114.39	61.94
1	1116.87	104	1054.77	1116.87	62.11
1	1125.19	103	1059.80	1125.19	65.39
1	1150.97	116	1093.41	1150.97	57.56
1	1154.37	117	1094.35	1154.37	60.01
1	1167.11	110	1107.31	1167.11	59.80
1	1181.06	101	1125.83	1181.06	55.23
1	1182.24	106	1122.97	1182.24	59.27
1	1197.58	108	1137.64	1197.58	59.95
1	1198.24	104	1136.87	1198.24	61.37
1	1202.08	103	1145.19	1202.08	56.90
1	1203.12	111	1142.90	1203.12	60.22
1	1238.36	117	1174.37	1238.36	63.99
1	1246.74	110	1177.11	1246.74	69.63
1	1254.26	106	1192.24	1254.26	62.02
1	1265.43	116	1200.97	1265.43	64.46
1	1271.17	112	1210.75	1271.17	60.42
1	1275.06	104	1208.24	1275.06	66.82
1	1282.28	108	1217.58	1282.28	64.70
1	1282.32	105	1211.29	1282.32	71.03

Table 6 (continued)

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Table 6 (continued)

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1	1202.32	103	1211.23	1202.32	71.03
1	1299.45	101	1231.06	1299.45	68.40
1	1312.88	118	1248.43	1312.88	64.45
1	1315.16	110	1256.74	1315.16	58.42
1	1318.64	106	1264.26	1318.64	54.38
1	1339.05	115	1274.30	1339.05	64.75
1	1340.36	102	1281.41	1340.36	58.95
1	1350.06	108	1292.28	1350.06	57.78
1	1351.17	105	1292.32	1351.17	58.85
1	1364.85	111	1303.55	1364.85	61.31
1	1374.23	109	1315.79	1374.23	58.44
1	1389.27	118	1322.88	1389.27	66.39
1	1389.76	106	1328.64	1389.76	61.12
1	1390.96	101	1329.45	1390.96	61.51
1	1395.91	103	1341.04	1395.91	54.88
1	1413.38	115	1359.05	1413.38	54.33
1	1415.62	105	1361.17	1415.62	54.44
1	1436.32	108	1380.06	1436.32	56.26
2	61.51	104	10.00	61.51	51.51
2	61.76	112	10.00	61.76	51.76
2	64.00	114	10.00	64.00	54.00
2	65.56	111	10.00	65.56	55.56
2	71.68	117	10.00	71.68	61.68
2	73.52	103	10.00	73.52	63.52
2	106.64	109	48.22	106.64	58.42
2	130.76	104	71.51	130.76	59.25
2	131.54	111	75.56	131.54	55.98
2	145.48	115	82.21	145.48	63.28
2	146.63	103	83.52	146.63	63.11
2	148.38	117	91.68	148.38	56.71
2	150.73	118	91.68	150.73	59.06
2	184.07	114	119.17	184.07	64.90
2	195.46	104	140.76	195.46	54.70
2	199.26	109	136.64	199.26	62.62
2	201.62	112	137.74	201.62	63.88
2	206.59	107	156.63	206.59	49.96
2	207.49	110	136.64	207.49	70.85
2	214.71	101	156.63	214.71	58.08
2	215.84	103	166.63	215.84	49.21
2	218.23	102	166.63	218.23	51.60
2	223.87	116	165.48	223.87	58.39
2	224.81	118	170.73	224.81	54.08
2	226.94	106	166.63	226.94	60.31
2	229.32	115	165.48	229.32	63.84
2	251.36	114	194.07	251.36	57.29

Table 6 (continued)

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Table 6 (continued)

2	262.62	113	194.07	262.62	68.55
2	272.21	104	215.46	272.21	56.75
2	279.39	107	216.59	279.39	62.80
2	280.90	110	217.49	280.90	63.42
2	288.65	105	225.84	288.65	62.81
2	291.06	103	225.84	291.06	65.22
2	299.36	117	232.46	299.36	66.90
2	315.35	116	253.87	315.35	61.48
2	318.08	112	251.62	318.08	66.46
2	323.03	114	271.36	323.03	51.68
2	333.05	106	266.94	333.05	66.11
2	342.46	109	282.68	342.46	59.78
2	357.56	102	293.45	357.56	64.10
2	359.60	104	292.21	359.60	67.40
2	384.36	117	319.36	384.36	65.00
2	386.00	111	327.68	386.00	58.33
2	387.24	115	320.80	387.24	66.44
2	391.08	114	333.03	391.08	58.04
2	400.49	106	343.05	400.49	57.44
2	422.87	109	362.46	422.87	60.41
2	425.88	101	364.04	425.88	61.85
2	428.00	103	365.16	428.00	62.83
2	445.39	112	386.41	445.39	58.99
2	454.16	118	396.72	454.16	57.44
2	462.84	114	401.08	462.84	61.76
2	488.12	116	431.79	488.12	56.33
2	491.68	106	430.49	491.68	61.19
2	499.55	101	445.88	499.55	53.67
2	501.41	104	442.44	501.41	58.98
2	502.05	109	442.87	502.05	59.18
2	503.67	105	445.59	503.67	58.08
2	505.32	103	448.00	505.32	57.33
2	506.97	108	448.00	506.97	58.97
2	529.86	111	474.99	529.86	54.87
2	543.78	118	484.16	543.78	59.62
2	545.20	113	484.10	545.20	61.10
2	560.58	106	501.68	560.58	58.90
2	576.55	102	517.72	576.55	58.83
2	577.43	108	516.97	577.43	60.46
2	587.61	116	518.12	587.61	69.49
2	599.54	117	551.43	599.54	48.11
2	604.08	110	540.28	604.08	63.81
2	630.72	114	573.94	630.72	56.78
2	633.59	111	579.86	633.59	53.73
2	645.09	101	578.38	645.09	66.71

Table 6 (continued)

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Table 6 (continued)   88

2	650.17	103	604.15	650.17	46.02
2	655.53	106	600.58	655.53	54.95
2	657.60	107	592.49	657.60	65.12
2	659.57	104	600.24	659.57	59.33
2	664.05	105	602.49	664.05	61.56
2	673.58	118	611.89	673.58	61.69
2	677.62	116	617.61	677.62	60.00
2	692.35	113	631.98	692.35	60.37
2	704.91	108	653.45	704.91	51.46
2	712.89	110	644.08	712.89	68.80
2	725.30	111	663.59	725.30	61.71
2	731.94	102	672.57	731.94	59.38
2	750.76	118	683.58	750.76	67.17
2	753.73	114	701.09	753.73	52.64
2	759.13	116	697.62	759.13	61.51
2	771.37	108	714.91	771.37	56.46
2	774.91	112	725.71	774.91	49.21
2	791.47	101	734.47	791.47	57.01
2	793.56	104	738.95	793.56	54.60
2	793.67	110	732.89	793.67	60.79
2	798.98	107	746.98	798.98	52.00
2	804.17	113	754.99	804.17	49.18
2	806.56	106	744.91	806.56	61.65
2	810.87	102	751.94	810.87	58.92
2	813.51	117	758.40	813.51	55.10
2	849.29	112	784.91	849.29	64.38
2	853.78	116	789.13	853.78	64.66
2	862.85	104	803.56	862.85	59.29
2	875.98	102	820.87	875.98	55.11
2	878.70	114	822.91	878.70	55.79
2	879.59	108	811.37	879.59	68.21
2	881.37	101	811.47	881.37	69.90
2	881.62	110	823.67	881.62	57.95
2	883.10	107	818.98	883.10	64.12
2	887.39	117	823.51	887.39	63.88
2	919.39	112	869.29	919.39	50.09
2	932.51	104	872.85	932.51	59.67
2	941.72	113	879.96	941.72	61.77
2	947.21	102	885.98	947.21	61.24
2	949.54	116	893.78	949.54	55.75
2	958.96	117	907.39	958.96	51.57
2	966.25	110	911.62	966.25	54.63
2	998.94	111	938.99	998.94	59.96
2	1003.49	105	948.69	1003.49	54.80
2	1004.26	104	952.51	1004.26	51.75

Table 6 (continued)

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Table 6 (continued)

2	1007.18	101	952.61	1007.18	54.58
2	1012.41	115	954.98	1012.41	57.43
2	1018.96	118	961.31	1018.96	57.65
2	1020.28	114	960.47	1020.28	59.81
2	1031.02	109	968.02	1031.02	63.00
2	1039.37	102	977.21	1039.37	62.15
2	1051.18	112	999.35	1051.18	51.83
2	1069.44	116	1016.96	1069.44	52.47
2	1076.17	104	1014.26	1076.17	61.91
2	1076.99	105	1013.49	1076.99	63.51
2	1087.28	113	1031.54	1087.28	55.74
2	1095.99	117	1036.61	1095.99	59.38
2	1096.25	110	1039.24	1096.25	57.01
2	1107.49	108	1042.98	1107.49	64.51
2	1109.78	103	1056.97	1109.78	52.81
2	1116.09	107	1056.49	1116.09	59.59
2	1130.85	112	1071.18	1130.85	59.68
2	1134.29	116	1079.44	1134.29	54.86
2	1146.62	105	1086.99	1146.62	59.63
2	1153.93	104	1086.17	1153.93	67.76
2	1159.34	113	1097.28	1159.34	62.06
2	1163.48	117	1105.99	1163.48	57.49
2	1168.94	109	1108.03	1168.94	60.91
2	1179.85	103	1119.78	1179.85	60.07
2	1205.91	112	1150.85	1205.91	55.05
2	1209.31	105	1156.62	1209.31	52.69
2	1220.58	118	1165.83	1220.58	54.75
2	1221.01	115	1159.74	1221.01	61.28
2	1226.22	104	1163.93	1226.22	62.29
2	1247.45	110	1187.16	1247.45	60.29
2	1249.99	107	1186.15	1249.99	63.84
2	1250.23	106	1187.93	1250.23	62.30
2	1251.82	113	1189.34	1251.82	62.48
2	1253.94	101	1190.06	1253.94	63.88
2	1258.14	103	1199.85	1258.14	58.29
2	1285.21	105	1229.31	1285.21	55.89
2	1292.89	116	1235.57	1292.89	57.32
2	1294.98	118	1230.58	1294.98	64.40
2	1300.93	111	1235.51	1300.93	65.42
2	1301.50	104	1246.22	1301.50	55.28
2	1315.28	114	1260.56	1315.28	54.71
2	1325.64	102	1260.53	1325.64	65.11
2	1345.93	110	1287.45	1345.93	58.48
2	1364.37	115	1298.33	1364.37	66.04

Table 6 (continued)

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Table 6 (continued)

2	1366.19	111	1310.93	1366.19	55.27
2	1370.21	117	1312.63	1370.21	57.58
2	1377.60	104	1321.50	1377.60	56.10
2	1386.88	114	1325.28	1386.88	61.60
2	1398.34	102	1335.64	1398.34	62.70
2	1398.86	107	1335.10	1398.86	63.76
2	1418.83	109	1357.71	1418.83	61.12
2	1433.74	112	1366.59	1433.74	67.15
2	1433.95	118	1372.56	1433.95	61.39
3	67.61	106	10.00	67.61	57.61
3	68.73	109	10.00	68.73	58.73
3	69.33	108	10.00	69.33	59.33
3	69.63	105	10.00	69.63	59.63
3	70.90	117	10.00	70.90	60.90
3	73.54	118	10.00	73.54	63.54
3	73.93	111	10.00	73.93	63.93
3	78.64	103	20.00	78.64	58.64
3	81.33	116	20.00	81.33	61.33
3	138.24	114	72.25	138.24	66.00
3	140.51	110	78.73	140.51	61.79
3	141.91	118	83.54	141.91	58.37
3	144.64	101	88.64	144.64	56.00
3	146.07	102	88.64	146.07	57.43
3	146.16	112	79.63	146.16	66.53
3	155.52	104	88.64	155.52	66.87
3	196.32	115	134.17	196.32	62.15
3	203.09	109	150.51	203.09	52.58
3	206.94	105	147.06	206.94	59.89
3	207.16	106	155.04	207.16	52.12
3	210.90	117	149.27	210.90	61.63
3	216.31	107	156.07	216.31	60.24
3	217.02	108	156.76	217.02	60.26
3	226.68	103	166.07	226.68	60.61
3	233.97	104	165.52	233.97	68.45
3	240.52	114	178.24	240.52	62.28
3	256.19	111	204.72	256.19	51.47
3	271.50	105	216.94	271.50	54.55
3	273.98	116	209.00	273.98	64.98
3	275.69	117	220.90	275.69	54.79
3	276.56	106	217.16	276.56	59.40
3	299.51	103	236.68	299.51	62.83
3	305.50	109	236.68	305.50	68.83
3	315.93	112	261.98	315.93	53.96
3	323.17	113	260.52	323.17	62.65
3	340.90	116	283.98	340.90	56.93

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Table 6 (continued)

3	344.84	118	288.33	344.84	56.51
3	350.27	106	296.56	350.27	53.71
3	360.91	105	301.50	360.91	59.41
3	370.36	102	309.51	370.36	60.85
3	380.26	111	320.14	380.26	60.12
3	400.24	113	343.17	400.24	57.07
3	408.04	118	354.84	408.04	53.20
3	410.44	115	348.22	410.44	62.22
3	416.50	109	365.76	416.50	50.75
3	417.55	106	360.27	417.55	57.28
3	436.87	108	370.71	436.87	66.16
3	437.74	104	377.65	437.74	60.09
3	445.05	103	380.36	445.05	64.69
3	457.57	111	400.26	457.57	57.30
3	470.76	116	413.12	470.76	57.64
3	472.42	117	415.40	472.42	57.02
3	490.77	113	430.24	490.77	60.53
3	500.16	106	437.55	500.16	62.61
3	500.43	109	436.50	500.43	63.93
3	504.05	104	447.74	504.05	56.31
3	505.26	105	445.60	505.26	59.65
3	506.01	108	446.87	506.01	59.14
3	515.47	102	455.05	515.47	60.41
3	515.65	107	454.69	515.65	60.97
3	517.00	103	455.05	517.00	61.94
3	526.73	112	463.35	526.73	63.38
3	548.06	115	498.07	548.06	49.98
3	566.53	108	516.01	566.53	50.52
3	566.79	105	515.26	566.79	51.53
3	570.26	117	512.42	570.26	57.85
3	570.42	113	500.77	570.42	69.65
3	574.27	104	514.05	574.27	60.22
3	581.08	109	510.43	581.08	70.65
3	583.81	103	527.00	583.81	56.82
3	617.72	112	556.73	617.72	60.99
3	618.00	116	560.74	618.00	57.26
3	633.80	118	572.90	633.80	60.90
3	636.81	113	580.42	636.81	56.39
3	665.21	105	606.79	665.21	58.43
3	666.12	106	606.98	666.12	59.13
3	669.10	102	612.29	669.10	56.81
3	682.97	109	621.08	682.97	61.90
3	690.02	116	628.00	690.02	62.02
3	699.06	112	637.72	699.06	61.34
3	703.38	117	641.17	703.38	62.21

Table 6 (continued)

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Table 6 (continued)

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3	705.46	113	646.81	705.46	58.65
3	727.95	101	677.67	727.95	50.28
3	746.72	103	680.63	746.72	66.09
3	764.13	111	703.27	764.13	60.85
3	772.46	115	717.34	772.46	55.13
3	774.72	109	712.97	774.72	61.75
3	778.05	113	715.46	778.05	62.59
3	782.82	118	726.02	782.82	56.80
3	821.45	102	755.19	821.45	66.26
3	836.09	111	784.13	836.09	51.96
3	837.78	116	775.15	837.78	62.63
3	839.80	109	784.72	839.80	55.07
3	853.95	118	792.82	853.95	61.13
3	873.20	113	808.05	873.20	65.14
3	882.31	105	827.56	882.31	54.75
3	884.85	107	821.64	884.85	63.21
3	893.66	102	831.45	893.66	62.21
3	904.72	109	849.80	904.72	54.92
3	914.26	115	855.09	914.26	59.17
3	922.04	112	861.88	922.04	60.17
3	933.43	117	871.31	933.43	62.12
3	952.77	113	893.20	952.77	59.57
3	961.00	103	905.19	961.00	55.81
3	961.03	108	897.91	961.03	63.12
3	963.37	107	904.85	963.37	58.52
3	988.50	111	926.25	988.50	62.25
3	1009.05	115	954.26	1009.05	54.79
3	1018.00	118	956.06	1018.00	61.94
3	1021.43	113	962.77	1021.43	58.66
3	1026.49	109	964.72	1026.49	61.77
3	1032.75	101	972.23	1032.75	60.52
3	1037.21	105	978.13	1037.21	59.09
3	1045.39	112	994.29	1045.39	51.10
3	1055.28	106	986.49	1055.28	68.79
3	1061.65	102	989.47	1061.65	72.17
3	1075.05	116	1021.73	1075.05	53.31
3	1087.75	113	1031.43	1087.75	56.32
3	1095.38	118	1038.00	1095.38	57.38
3	1119.31	109	1056.49	1119.31	62.83
3	1124.83	102	1071.65	1124.83	53.18
3	1128.84	107	1065.54	1128.84	63.31
3	1135.75	112	1075.39	1135.75	60.36
3	1159.36	113	1097.75	1159.36	61.61
3	1168.89	118	1105.38	1168.89	63.51

Table 6 (continued)   97

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Table 6 (continued)   98

3	1176.41	115	1112.36	1176.41	64.05
3	1181.22	101	1125.93	1181.22	55.29
3	1184.74	105	1130.39	1184.74	54.35
3	1197.57	109	1139.31	1197.57	58.25
3	1199.26	104	1136.82	1199.26	62.44
3	1202.41	102	1144.83	1202.41	57.58
3	1204.82	112	1145.75	1204.82	59.07
3	1232.88	113	1169.36	1232.88	63.52
3	1243.23	118	1188.89	1243.23	54.33
3	1249.78	116	1179.09	1249.78	70.69
3	1251.18	105	1194.74	1251.18	56.44
3	1259.91	108	1203.96	1259.91	55.95
3	1267.09	106	1206.04	1267.09	61.04
3	1268.57	109	1207.57	1268.57	61.01
3	1271.23	103	1213.94	1271.23	57.29
3	1316.79	115	1257.10	1316.79	59.69
3	1326.38	108	1269.91	1326.38	56.47
3	1330.33	112	1264.82	1330.33	65.51
3	1336.66	105	1281.18	1336.66	55.47
3	1338.77	106	1277.09	1338.77	61.69
3	1344.93	109	1298.57	1344.93	46.36
3	1347.39	103	1291.23	1347.39	56.16
3	1382.95	117	1320.59	1382.95	62.36
3	1384.48	115	1326.79	1384.48	57.69
3	1397.90	111	1344.54	1397.90	53.36
3	1401.82	113	1342.88	1401.82	58.94
3	1406.18	107	1349.88	1406.18	56.30
3	1418.99	102	1355.86	1418.99	63.13
3	1421.92	109	1354.93	1421.92	66.99

Table 6 (continued)

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Table 6 (continued)

APPENDIX D

OUTPUT OF MICRO SAINT MODEL USING A DISTRIBUTION OF PERSONNEL BY
APTITUDE (LOW, MEDIUM, HIGH) FOR SHELTERS 3, 9, 10, 17, AND 18

OUTPUT OF MICRO SAINT MODEL USING A DISTRIBUTION OF PERSONNEL BY APTITUDE (LOW, MEDIUM, HIGH) FOR SHELTERS 3, 9, 10, 17, AND 18

run	clock	msg1cum	msg2cum	msg3cum	msg4cum	msg5cum
1	1440.10	1320.00	840	560	640	670
2	1440.10	960.00	870	580	680	760
3	1440.10	1240.00	870	560	660	800

Table 7.

Data1.res output file: low aptitude personnel assigned to shelters 3, 9, 10, 17, and 18

msg6cum	msg7cum	msg8cum	msg9cum	msg10cum	msg11cum	msg12cum
590	510	750	580	620	1000	870
900	750	780	740	740	1230	990
830	780	840	720	100	1020	900

Table 7 (continued)

msg13cum	msg14cum	msg15cum	msg16cum	msg17cum	msg18cum
180	180	1050	950	680	700
750	780	1080	1020	500	500
1230	270	930	820	640	640

Table 7 (continued)

Trigger
end of run
end of run
end of run

Table 7 (continued)

run	clock	msg1cum	msg2cum	msg3cum	msg4cum	msg5cum
1	1440.10	1320.00	840	840	640	670
2	1440.10	960.00	870	870	680	760
3	1440.10	1240.00	870	840	660	800

Table 8.

*Data 1.res output file: medium aptitude personnel assigned
to shelters 3, 9, 10, 17, and 18*

msg6cum	msg7cum	msg8cum	msg9cum	msg10cum	msg11cum	msg12cum
590	510	750	870	930	1000	870
900	750	780	1110	1110	1230	990
830	780	840	1080	150	1020	900

Table 8 (continued)

msg13cum	msg14cum	msg15cum	msg16cum	msg17cum	msg18cum
180	180	1050	950	1020	1050
750	780	1080	1020	750	750
1230	270	930	820	960	960

Table 8 (continued)

Trigger
end of run
end of run
end of run

Table 8 (continued)

run	clock	msg1cum	msg2cum	msg3cum	msg4cum	msg5cum
1	1440.10	1320.00	840	1120	640	670
2	1440.10	960.00	870	1160	680	760
3	1440.10	1240.00	870	1120	660	800

Table 9.

Data1.res output file: high aptitude personnel assigned to shelters 3, 9, 10, 17, and 18

msg6cum	msg7cum	msg8cum	msg9cum	msg10cum	msg11cum	msg12cum
590	510	750	1160	1240	1000	870
900	750	780	1480	1480	1230	990
830	780	840	1440	200	1020	900

Table 9 (continued)

msg13cum	msg14cum	msg15cum	msg16cum	msg17cum	msg18cum
180	180	1050	950	1360	1400
750	780	1080	1020	1000	1000
1230	270	930	820	1280	1280

Table 9 (continued)

Trigger
end of run
end of run
end of run

Table 9 (continued)

run	clock	crew[1]	msg1cum	crew[2]	msg2cum	crew[3]
1	0.00	0	0.00	0	0	0
1	360.00	9	520.00	18	210	21
1	720.00	9	800.00	18	390	21
1	1080.00	10	920.00	17	510	21
1	1440.00	10	1320.00	17	840	21
2	0.00	0	0.00	0	0	0
2	360.00	9	160.00	18	150	21
2	720.00	9	440.00	18	420	21
2	1080.00	10	760.00	17	660	21
2	1440.00	10	960.00	17	870	21
3	0.00	0	0.00	0	0	0
3	360.00	9	280.00	18	210	21
3	720.00	9	560.00	18	420	21
3	1080.00	10	920.00	17	630	21
3	1440.00	10	1240.00	17	870	21

Table 10.

Data2.res output file: low aptitude personnel assigned to shelters 3, 9, 10, 17, and 18

msg3cum	crew[4]	msg4cum	crew[5]	msg5cum	crew[6]	msg6cum
0	0	0	0	0	0	0
140	16	160	16	120	16	140
280	12	340	13	330	13	350
360	17	520	16	430	14	440
560	13	640	13	670	11	590
0	0	0	0	0	0	0
100	16	140	16	100	16	180
280	12	350	13	310	13	450
460	17	470	16	430	14	720
580	13	680	13	760	11	900
0	0	0	0	0	0	0
140	16	100	16	140	16	140
280	12	310	13	380	13	410
400	17	450	16	560	14	620
560	13	660	13	800	11	830

Table 10   (continued)

crew[7]	msg7cum	crew[8]	msg8cum	crew[9]	msg9cum	crew[10]
0	0	0	0	0	0	0
14	240	12	210	16	180	16
12	450	11	390	16	380	16
14	510	13	510	16	480	16
14	510	12	750	16	580	16
0	0	0	0	0	0	0
14	150	12	150	16	180	16
12	360	11	390	16	400	16
14	630	13	630	16	560	16
12	750	12	780	16	740	16
0	0	0	0	0	0	0
14	210	12	180	16	120	16
12	420	11	420	16	340	16
14	600	13	600	16	560	16
12	780	12	840	16	720	16

Table 10 (continued)

msg10cum	crew[11]	msg11cum	crew[12]	msg12cum	crew[13]	msg13cum
0	0	0	0	0	0	0
200	10	320	12	240	13	180
400	11	410	12	360	13	180
500	10	730	14	570	13	180
620	11	1000	14	870	13	180
0	0	0	0	0	0	0
160	10	440	12	240	13	180
380	11	770	12	570	12	390
560	10	1050	14	810	12	570
740	11	1230	14	990	11	750
0	0	0	0	0	0	0
100	10	160	12	120	13	330
100	11	400	12	360	12	540
100	10	720	14	630	12	750
100	11	1020	14	900	11	1230

Table 10   (continued)

crew[14]	msg14cum	crew[15]	msg15cum	crew[16]	msg16cum	crew[17]
0	0	0	0	0	0	0
15	180	14	300	14	300	16
15	180	11	510	11	510	16
15	180	14	720	16	650	16
15	180	11	1050	13	950	16
0	0	0	0	0	0	0
15	240	14	270	14	270	16
13	450	11	630	11	660	16
14	600	14	900	16	840	16
12	780	11	1080	13	1020	16
0	0	0	0	0	0	0
15	270	14	210	14	180	16
15	270	11	450	11	420	16
15	270	14	660	16	580	16
15	270	11	930	13	820	16

Table 10   (continued)

msg17cum	crew[18]	msg18cum	Trigger
0	0	0	clock
220	16	220	clock
420	16	420	clock
520	16	540	clock
680	16	700	clock
0	0	0	clock
160	16	140	clock
300	16	300	clock
420	16	400	clock
500	16	500	clock
0	0	0	clock
120	16	120	clock
260	16	260	clock
420	16	420	clock
640	16	640	clock

Table 10   (continued)

run	clock	crew[1]	msg1cum	crew[2]	msg2cum	crew[3]
1	0.00	0	0.00	0	0	0
1	360.00	9	520.00	18	210	16
1	720.00	9	800.00	18	390	16
1	1080.00	10	920.00	17	510	16
1	1440.00	10	1320.00	17	840	16
2	0.00	0	0.00	0	0	0
2	360.00	9	160.00	18	150	16
2	720.00	9	440.00	18	420	16
2	1080.00	10	760.00	17	660	16
2	1440.00	10	960.00	17	870	16
3	0.00	0	0.00	0	0	0
3	360.00	9	280.00	18	210	16
3	720.00	9	560.00	18	420	16
3	1080.00	10	920.00	17	630	16
3	1440.00	10	1240.00	17	870	16

Table 11.

Data2.res output file: medium aptitude personnel assigned to shelters 3, 9, 10, 17, and 18

msg3cum	crew[4]	msg4cum	crew[5]	msg5cum	crew[6]	msg6cum
0	0	0	0	0	0	0
210	16	160	16	120	16	140
420	12	340	13	330	13	350
540	17	520	16	430	14	440
840	13	640	13	670	11	590
0	0	0	0	0	0	0
150	16	140	16	100	16	180
420	12	350	13	310	13	450
690	17	470	16	430	14	720
870	13	680	13	760	11	900
0	0	0	0	0	0	0
210	16	100	16	140	16	140
420	12	310	13	380	13	410
600	17	450	16	560	14	620
840	13	660	13	800	11	830

Table 11   (continued)

crew[7]	msg7cum	crew[8]	msg8cum	crew[9]	msg9cum	crew[10]
0	0	0	0	0	0	0
14	240	12	210	11	270	11
12	450	11	390	11	570	11
14	510	13	510	11	720	11
14	510	12	750	11	870	11
0	0	0	0	0	0	0
14	150	12	150	11	270	11
12	360	11	390	11	600	11
14	630	13	630	11	840	11
12	750	12	780	11	1110	11
0	0	0	0	0	0	0
14	210	12	180	11	180	11
12	420	11	420	11	510	11
14	600	13	600	11	840	11
12	780	12	840	11	1080	11

Table 11   (continued)

msg10cum	crew[11]	msg11cum	crew[12]	msg12cum	crew[13]	msg13cum
0	0	0	0	0	0	0
300	10	320	12	240	13	180
600	11	410	12	360	13	180
750	10	730	14	570	13	180
930	11	1000	14	870	13	180
0	0	0	0	0	0	0
240	10	440	12	240	13	180
570	11	770	12	570	12	390
840	10	1050	14	810	12	570
1110	11	1230	14	990	11	750
0	0	0	0	0	0	0
150	10	160	12	120	13	330
150	11	400	12	360	12	540
150	10	720	14	630	12	750
150	11	1020	14	900	11	1230

Table 11   (continued)

crew[14]	msg14cum	crew[15]	msg15cum	crew[16]	msg16cum	crew[17]
0	0	0	0	0	0	0
15	180	14	300	14	300	11
15	180	11	510	11	510	11
15	180	14	720	16	650	11
15	180	11	1050	13	950	11
0	0	0	0	0	0	0
15	240	14	270	14	270	11
13	450	11	630	11	660	11
14	600	14	900	16	840	11
12	780	11	1080	13	1020	11
0	0	0	0	0	0	0
15	270	14	210	14	180	11
15	270	11	450	11	420	11
15	270	14	660	16	580	11
15	270	11	930	13	820	11

Table 11   (continued)

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msg17cum	crew[18]	msg18cum	Trigger
0	0	0	clock
330	11	330	clock
630	11	630	clock
780	11	810	clock
1020	11	1050	clock
0	0	0	clock
240	11	210	clock
450	11	450	clock
630	11	600	clock
750	11	750	clock
0	0	0	clock
180	11	180	clock
390	11	390	clock
630	11	630	clock
960	11	960	clock

Table 11   (continued)

run	clock	crew[1]	msg1cum	crew[2]	msg2cum	crew[3]
1	0.00	0	0.00	0	0	0
1	360.00	9	520.00	18	210	6
1	720.00	9	800.00	18	390	6
1	1080.00	10	920.00	17	510	6
1	1440.00	10	1320.00	17	840	6
2	0.00	0	0.00	0	0	0
2	360.00	9	160.00	18	150	6
2	720.00	9	440.00	18	420	6
2	1080.00	10	760.00	17	660	6
2	1440.00	10	960.00	17	870	6
3	0.00	0	0.00	0	0	0
3	360.00	9	280.00	18	210	6
3	720.00	9	560.00	18	420	6
3	1080.00	10	920.00	17	630	6
3	1440.00	10	1240.00	17	870	6

Table 12.

Data2.res output file: high aptitude crews assigned to shelters 3, 9, 10, 17, and 18

msg3cum	crew[4]	msg4cum	crew[5]	msg5cum	crew[6]	msg6cum
0	0	0	0	0	0	0
280	16	160	16	120	16	140
560	12	340	13	330	13	350
720	17	520	16	430	14	440
1120	13	640	13	670	11	590
0	0	0	0	0	0	0
200	16	140	16	100	16	180
560	12	350	13	310	13	450
920	17	470	16	430	14	720
1160	13	680	13	760	11	900
0	0	0	0	0	0	0
280	16	100	16	140	16	140
560	12	310	13	380	13	410
800	17	450	16	560	14	620
1120	13	660	13	800	11	830

Table 12 (continued)

crew[7]	msg7cum	crew[8]	msg8cum	crew[9]	msg9cum	crew[10]
0	0	0	0	0	0	0
14	240	13	210	4	360	4
12	450	12	390	4	760	4
14	510	13	510	4	960	4
14	510	12	750	4	1160	4
0	0	0	0	0	0	0
14	150	13	150	4	360	4
12	360	12	390	4	800	4
14	630	13	630	4	1120	4
12	750	12	780	4	1480	4
0	0	0	0	0	0	0
14	210	13	180	4	240	4
12	420	12	420	4	680	4
14	600	13	600	4	1120	4
12	780	12	840	4	1440	4

Table 12 (continued)

msg10cum	crew[11]	msg11cum	crew[12]	msg12cum	crew[13]	msg13cum
0	0	0	0	0	0	0
400	10	320	12	240	13	180
800	11	410	12	360	13	180
1000	10	730	14	570	13	180
1240	11	1000	14	870	13	180
0	0	0	0	0	0	0
320	10	440	12	240	13	180
760	11	770	12	570	12	390
1120	10	1050	14	810	12	570
1480	11	1230	14	990	11	750
0	0	0	0	0	0	0
200	10	160	12	120	13	330
200	11	400	12	360	12	540
200	10	720	14	630	12	750
200	11	1020	14	900	11	1230

Table 12 (continued)

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crew[14]	msg14cum	crew[15]	msg15cum	crew[16]	msg16cum	crew[17]
0	0	0	0	0	0	0
15	180	14	300	14	300	4
15	180	11	510	11	510	4
15	180	14	720	16	650	4
15	180	11	1050	13	950	4
0	0	0	0	0	0	0
15	240	14	270	14	270	4
13	450	11	630	11	660	4
14	600	14	900	16	840	4
12	780	11	1080	13	1020	4
0	0	0	0	0	0	0
15	270	14	210	14	180	4
15	270	11	450	11	420	4
15	270	14	660	16	580	4
15	270	11	930	13	820	4

Table 12 (continued)

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msg17cum	crew[18]	msg18cum	Trigger
0	0	0	clock
440	4	440	clock
840	4	840	clock
1040	4	1080	clock
1360	4	1400	clock
0	0	0	clock
320	4	280	clock
600	4	600	clock
840	4	800	clock
1000	4	1000	clock
0	0	0	clock
240	4	240	clock
520	4	520	clock
840	4	840	clock
1280	4	1280	clock

Table 12 (continued)

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